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Presented to
the



by
Prof. F. W. W. W. W.
1890

Clapham

THE GROUND BENEATH US,
ITS GEOLOGICAL PHASES AND CHANGES:

BEING

THREE LECTURES

ON

THE GEOLOGY OF CLAPHAM,

AND THE

NEIGHBOURHOOD OF LONDON GENERALLY,

DELIVERED TO THE

MEMBERS OF THE CLAPHAM ATHENÆUM, CLAPHAM COMMON,

ON 1ST MAY, 1854, AND 7TH AND 21ST APRIL, 1856,

BY

JOSEPH PRESTWICH, F.R.S., F.G.S., ETC.



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P R E F A C E.

ERRATA AND CORRIGENDA.

- Page 7, line 25, *for commonness read commonness.*
— 20, — 7, *insert always after not.*
— 38, — 9, *for extends read extend.*
— 41, — 2, *for smallest creatures, are amongst the most minute and obscure of any now read smallest fossils, are also amongst the most minute and obscure of any creatures now.*
— 70, — 14, *for Woolwich read Rochester.*
— 78, — 17, *for the read their.*
Plate I., *for Reding read Roding.*
— I., *for Guilford read Guildford.*
— I., *for Dorent read Darent.*
— II., *for Thanet Sand read Thanet Sands.*
— II., *for green read green and yellow.*
— II., *end the bracket of the Woolwich and Reading series at "bright" instead of "sand."*

to avoid as much as possible all technical language and local details. I wished, nevertheless, to point out, however slightly, all those leading geological phenomena which are within the reach of all who care to observe,—to show how to proceed with an inquiry into the causes which produced them by a careful study of effects,—and to give some insight into the chief objects of geological inquiry. At the same time the subject is one of more than local interest, for Clapham stands upon ground which forms part of the London Tertiary district, and consequently the account here given of the Drift and of the Tertiary strata is equally applicable to the ground beneath London and to some distance around; and no separate work having yet been published of the Geology of London and its neighbourhood, and this account, though general, touching upon most of the leading points,



P R E F A C E.

THE following Lectures, given at the instance of some of my friends at Clapham, were not written with a view to publication, as I contemplated the possibility of undertaking at some future period a more special work on the subject. Having, however, been favoured by a request to print them, accompanied by a liberal offer to join me in the expenses, on the part of the Council of the Clapham Athenæum, I have revised them for publication in their original form, with the addition of a few explanatory notes. They do not by any means aim at a complete account of the geology of the district; for, considering that the subject was probably new to many of the younger Members present, I endeavoured to treat it in a popular manner, and to avoid as much as possible all technical language and local details. I wished, nevertheless, to point out, however slightly, all those leading geological phænomena which are within the reach of all who care to observe,—to show how to proceed with an inquiry into the causes which produced them by a careful study of effects,—and to give some insight into the chief objects of geological inquiry. At the same time the subject is one of more than local interest, for Clapham stands upon ground which forms part of the London Tertiary district, and consequently the account here given of the Drift and of the Tertiary strata is equally applicable to the ground beneath London and to some distance around; and no separate work having yet been published of the Geology of London and its neighbourhood, and this account, though general, touching upon most of the leading points,

besides including a short discussion of some views not yet brought forward elsewhere, especially those respecting the Drift, I trust that this sketch may also be of some use as a guide to those even who have made Geology more particularly their study, and that it may supply for the present the want of a more special treatise. For those who in the mean time wish for fuller information, I would refer to the various papers and notices by Parkinson¹, Conybeare and Phillips², Dr. Buckland³, Dr. Mitchell⁴, Wetherell⁵, Morris⁶, Edwards⁷, Prof. Owen⁸, Sir Charles Lyell⁹, De la Condamine¹⁰, Bowerbank¹¹, Mylne¹², myself¹³ and others. The illustrations of these Lectures, although necessarily of the most simple description, are, as far as possible, characteristic. Some are copied from other works, and some are drawn from original specimens, any additions to the specimen being marked in dotted lines. I am much indebted to the artist and geologist, Mr. Samuel Mackie, for so well exhibiting in mere outlines the essential characters of the fossils.

¹ Transactions of the Geological Society, vol. i. p. 324.

² The Geology of England and Wales.

³ Trans. Geol. Soc. vol. iv. p. 277; and 2nd ser. vol. ii. p. 119.

⁴ Proceedings of the Geological Society, vol. i. p. 481; ii. p. 7.

⁵ *Ibid.* vol. i. pp. 403, 417; ii. p. 93; iii. p. 140. Trans. Geol. Soc. 2nd ser. vol. v. p. 133. Philosophical Magazine, 3rd ser. vol. i. p. 233; vol. ix. p. 462; vol. xv. p. 540. History and Antiquities of Highgate, p. 133.

⁶ *Ibid.* vol. ii. p. 450. *Ibid.* 3rd ser. vol. xi. p. 104. Magazine of Natural History, 1st ser. vol. viii. p. 356; vol. ix. p. 261; 2nd ser. vol. ii. p. 539. Quarterly Journal of the Geological Society, vol. vi. p. 201. (This last work, which contains most of the later papers on the Geology of the London district, is published and sold by Messrs. Longman and Co.)

⁷ Publications of the Palæontographical Society.

⁸ *Ibid.* See also notes to text.

⁹ Manual of Elementary Geology, 5th Edit., chap. x. xiii. and xvi.

¹⁰ Journ. Geol. Soc. vol. vi. p. 440.

¹¹ The Fossil Fruits of Sheppey.

¹² Sections of the Strata beneath London. Geological Map of London.

¹³ Journ. Geol. Soc. vol. iii. pp. 354, 378; vol. vi. p. 252; vol. viii. p. 235; vol. x. pp. 75, 401; vol. xi. p. 206; and vol. xiii. p. 89. The Water-bearing Strata of London, §§ 2 and 4.

10 Kent Terrace,
Regent's Park Road,
Oct. 1857.

THE GROUND BENEATH US, ITS GEOLOGICAL PHASES AND CHANGES.

FIRST LECTURE.

POST-PLIOCENE PERIOD.

INTRODUCTION. ON THE ORIGIN OF THE GRAVEL, AND ON THE CONFIGURATION OF THE SURFACE (*b*, Pl. II.).

IN these Lectures it will be my object briefly to describe the nature and character of those geological changes of which the immediate vicinity of London, and Clapham in particular, has been the scene*. I will therefore limit my observations to those phænomena only of which the records are preserved or indicated in the strata beneath and near the spot where we are now assembled; and, while abstaining from all technical descriptions that would be unintelligible without preliminary studies, I will yet endeavour, so far as time will allow, to give you not only the principal results arrived at by geologists, but also a general statement of the mode by which the several problems have been or are being worked out†.

* The section in Pl. II. of the ground beneath Clapham corresponds in all its leading features with many sections that might be taken in the central and western parts of London.

† Possibly some of these questions may already have been brought before you by a late distinguished geologist, for several years a resident here. I allude to Dr. Mantell, whose felicity of expression and poetical feeling were as remarkable as his zeal was great. He took especial interest in palæontological¹ researches. This inquiry having to a greater extent reference to physical questions, I hope to avoid going over ground with which you have already been made acquainted. Some notice of the geology of this district, by Dr. Mantell, will be found in his 'Sketch of the Geology of Surrey,' inserted in the first volume of Brayley's 'History of Surrey,' 1850.

¹ Relating to old extinct animals.

We are naturally so much impressed by the beauty of existing nature, by the apparent permanence of the orders of animals and of plants now living, and by their complete possession of, and adaptation to, the present surface of the earth, that we can hardly conceive that beneath an exterior so fully and admirably adorned, there exist the wrecks and ruins of former surfaces of the earth, once probably as rich, teeming, and diversified as the one on which we move. The present terrestrial surface is, in fact, but a film over the solid frame of our planet; and the composition of the various plants and animals which flourish on it is such, that, let life cease, its whole organic structure would crumble down, and leave scarcely a trace behind. How difficult then would it be after the lapse of a few years to picture the beauty and variety of the present scene! And so it is now with respect to the past; entombed in the rocks and ground beneath us are the remains of former surfaces of this planet, but of the then existing plants and animals comparatively few traces are left,—their living forms have passed away, and all that remains of them are a few pieces of the harder skeleton, or a few leaf-impressions and fragments of wood, preserved by chance and protected from decay in the sediment deposited in the beds of former seas and lakes,—sediments now in part hardened into stone, and forming the solid rocks of our hills and valleys. It is in the restoration of these old forms of plants and animals, in the just conception of the part they filled at a former period of the earth's history, and in the study of the changes which led to the successive appearance and disappearance of the many distinct species, that the labours of the geologist in a great measure consist. He has, from a few detached facts, to fill up a living picture; so to identify himself with the past, as to describe, and follow, as though an eye-witness, the different changes which have at various periods so greatly modified the surface of the earth.

I must premise that rocks, in which term we include not only the hard stony strata*, but also the soft strata of clay and sand, are divided into two classes, viz. those of igneous origin, such as Volcanic Rocks and Granite, and those of sedimentary origin, as the Portland Stone, the Chalk, and the London Clay. This latter class consists of those which have been accumulated

* Strata,—the parallel layers of a rock.

in the ancient seas and lakes of the earth, and they are either unconsolidated as originally deposited, or else are hardened into stone by chemical agency or by heat*. In these sedimentary rocks the strata are either fine- or coarse-grained, according to the strength of the tides or currents, which swept down from the ancient lands the materials of which they are composed. Consequently some strata have been formed of fine silt or clay, others of sand more or less coarse, and others again, in cases in which the moving power of the sea or rivers has been greater, of rolled fragments of rocks. These latter form conglomerate strata, that is to say, they are full of pebbles or of fragments of rocks more or less worn, and which can generally be recognized by their mineral character or their fossils as having been derived from other pre-existing rocks, sometimes adjacent and sometimes at a distance from the spot. There is another class of deposits formed likewise of detrital† materials, but irregularly scattered and loose on the surface, and not stratified: they constitute superficial deposits of gravel and brick-earth, and belong to what geologists formerly termed Diluvium, but which they now more frequently denominate "Drift."

I must also ask you to discard from your minds any feeling of indifference or slight that your familiarity with the materials we deal with might engender. I can understand the difficulty which those who are not geologists may experience, in dissociating the homeliness and commonness of the substances amongst which we have to work, from the abstract beauty and grandeur of the inquiry itself—in not allowing the rudeness of the tablet to call off attention from the value of the inscriptions. Although dealing with rough rocks and stones, using familiar names, and, in the absence of more perfect specimens, noticing even the smallest fragments that show defined form and structure ‡, the true object of our research does not lie in the collecting of a mineral or of a fossil, or in the determination of a certain arrangement of rock masses, whatever interest may attach to these cognate branches separately—these are merely the means, and not the end;—but, commencing

* Either volcanic or central heat.

† Broken up.

‡ Carefully avoiding all mere general resemblances, which are most fallacious. We require *identity* of some part or other, however small.

with the present world as our starting-point, we have to trace back, through bygone ages, the wonderful physical vicissitudes to which this earth has been subject,—to determine with care and reverence the remarkable changes in organic life which have successively taken place on its surface—comparing each creation with that existing at the present day,—to discover its relations therewith, in what respect and to what extent it differs, and the position it occupies in the chain of created things,—a chain of which only a portion of the links remain with us now, and of which the others belong to periods long past by. To do this successfully and properly, we must not overlook either little things or common things, but take all as they offer themselves,—overlook nothing,—give to each its due weight and place, and read off, as best we can, the lesson they impart; for after all our care, and with the closest attention, the reconstruction is but fragmentary,—we cannot follow the history of the earth uninterruptedly, or always correctly. Still there are now a certain number of well-established positions, and although geologists may differ as to the mode in which certain phænomena have arisen, we all agree in respect to the main and essential results.

With reference to the ground immediately beneath us, I will commence with the surface, and, proceeding downwards*, see what evidence we have of former conditions and of other and older lands having here preceded the present one.

The vegetable soil, although now constituting so conspicuous a feature, and performing so important a part, is, geologically speaking, of little moment, as it contains no fossils, and has been formed principally by causes at present in action, such as the disintegration of the surface of the underlying rocks, and the decomposition of vegetable matter. It rarely exceeds a few feet in thickness, and often is not more than a few inches thick.

Immediately under the soil we find in this neighbourhood a mass or bed of ochreous-coloured gravel, varying in thickness from about 3 to 12 feet†. It spreads over the greater part of this Common, a large portion of London stands upon it, and it

* On any other occasion I should prefer beginning with the older, and proceeding upwards to the newer strata.

† It is not marked in the map: the regular strata only are there given.

stretches east and west for many miles along the valley of the Thames, reposing through the greater extent of this area, upon a mass of dark-coloured tenacious clay (*h*, Pl. II.). This gravel being permeable by water, a portion of the rain which falls on its surface passes into it, but, on reaching the clay beneath, is stopped by and lodges on the surface of that clay, forming an under-ground sheet of water in the lower part of the gravel. Consequently when wells are dug in this gravel, on arriving within a few feet of the clay, the stored-up water is everywhere met with, and filters cool and clear into the bottom of these wells. In the same way the water so held in the body of the gravel flows out in natural springs on the slopes of those hills where the gravel is cut off by valleys penetrating into the clay beneath (*s*, fig. 17, p. 30). It is these gravel-beds which form the great source of water-supply to all the shallow wells and land springs of London and its immediate neighbourhood,—including the spring-well on this Common, the spring on Rush Hill, and all the noted old pumps of the City and Westminster.

Let us now study the gravel more closely, look to its past history, and trace its origin by carefully analysing its character and questioning its every feature. I must, however, first mention, that the classification of the gravels around London is yet a geological inquiry under discussion. I believe that these beds will have to be referred to more ages than one, for I find that they occur on several different levels, and that organic remains are not dispersed equally through all of them. For instance, at Clapham I am not aware that any have hitherto been found, whereas they have been met with in many parts of London, and at Kew, Brentford, Clapton, Hackney* and elsewhere, often in considerable abundance. Although this is not the place to discuss this special, and at present debateable question, I may give you some of the more general conclusions at which we have arrived. At the same time our present purpose will be answered, and the subject simplified, if we consider the gravels of Clapham and of the neighbourhood of London generally as belonging to one nearly contemporaneous epoch, and

* See Quart. Journ. Geol. Soc. vol. vi. p. 201, and vol. xi. p. 107, for details of their occurrence at some of these localities.

treat of it as a whole. The theoretical questions we have to investigate are,—

1st, Whence did the gravel originally come?, 2nd, by what means was it brought into its present situation?, and 3rd, at what geological period was it spread over the surfaces where we now find it?

With regard to the first question, we must minutely examine the gravel, see what are its component parts, and determine whence they were derived. You will find that it consists of angular stones, with their edges slightly worn (fig. 1), and of pebbles perfectly rounded (fig. 2), imbedded in a coarse sili-

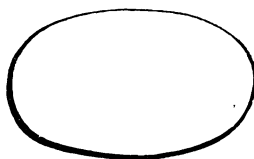
Form of Materials from the Gravel of Clapham Common.

Fig. 1.



Subangular Flint.

Fig. 2.



Flint Pebble.

ceous sand* mixed with a small proportion of clay, and the whole coloured by the oxides of iron†. It may be asked, “May not all the parts of this gravel have been formed where found by ordinary direct deposition in a sea or by segregation?” This cannot be the case, because the mass is neither homogeneous nor simply concretionary,—the pebbles are different from the sand, the sand from the clay, and the colouring matter does not enter into the substance of the pebbles or sand, but merely coats their surface‡; each thing is independent, and cannot have been separated out of one common mass. Another reason is, that the stones and pebbles forming the gravel do not contain any remains of the animals which lived at the time the gravel was formed, but, on the contrary, they

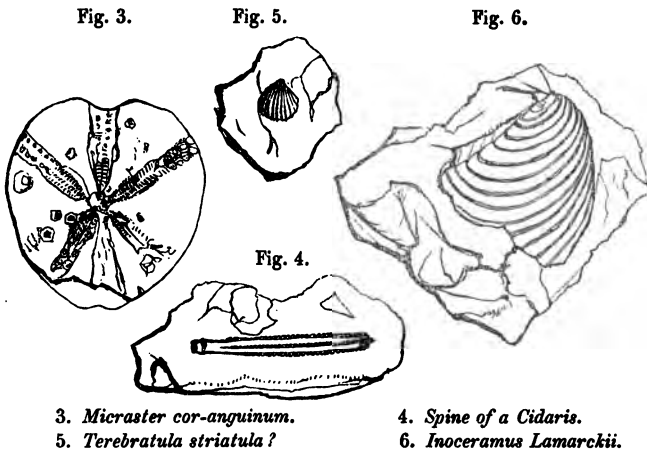
* As the sand on the shore at Dover or Brighton.

† Rust is an oxide of iron.

‡ As you may see when gravel has been long exposed in walks or elsewhere to the atmosphere how it loses its colour by the washing away of the colouring matter.

contain remains of animals of an entirely different and older period; they must, therefore, have been derived from some older and pre-existing rock or rocks. We further find that, although the component parts of the gravel differ in external appearance, yet that by much the greater portion of it is composed of the same material, and that material is the common black flint. The broken specimens show internally the same texture, although externally the wear and staining to which they have been subjected have often much changed their appearance. In the interior of some of these flints, and upon the outer surface of others, you will frequently find casts and impressions of well-marked and peculiar fossils*; and as certain fossils characterize certain rocks, there will be no difficulty, if we can recognize the species of these fossils, to determine the rock-formation from which these flints are derived. Amongst the fossils so found are the remains of sponges, also of various sea-urchins (fig. 3), spines (fig. 4) and shells (figs. 5, 6).

Casts of Fossils in Flint from the Gravel of Clapham and London.



Now all these are fossils common in the Chalk, and belong to species which do not occur in any formation newer than the

* Dr. Mantell figures four specimens of chalk fossils in flint from the gravel of the Common.—*Op. cit.*

chalk, nor in any older than the Cretaceous group (*m-n*, Pl I.). Therefore both the mineral structure (although this alone would not suffice, as varieties of flints are found in other formations than the chalk), and the organic remains, go to show that the great bulk of the pebbles and stones of the gravel of this district are derived from the chalk. But the gravel reposes here upon a thick bed of clay of a very different age, and no chalk is found near. Consequently it must be from some distant spot that the materials for the gravel have been derived, and you will see in the geological map (Pl. I.) that the nearest place where any extent of chalk is exposed is in the range of hills passing by Croydon, Carshalton, Ewell, and Epsom, a distance of six to ten miles southward from Clapham.

Yet although flints form by far the larger proportion of the gravel, there are a few other substances showing a different origin. First there are some subangular flattish fragments of a hard, light-coloured, porous stone, and of a brown horny-looking flint. Now we have no rocks or minerals like these, either in the tertiary strata around London, or in the chalk; but beyond the chalk-hills, and rising up from beneath them, are a series of strata known as the Upper and Lower Greensands (Sect. 1, Pl. I.), some of the lower beds of which latter may be well seen in the cutting where the Brighton and Dover Railways diverge at Redhill. This formation, which extends thence to Dorking and Farnham, contains some beds of rock (Ragstone) and of a sort of flint called Chert, and it is worn fragments of these that we here recognize in the gravel. This evidence is thus corroborative, and shows that the gravel of Clapham and London consists essentially of the debris of rocks, transported northward probably from the hills of Surrey and Sussex, and over distances of not less than from six to twenty miles.

There is, however, a certain amount of conflicting evidence, for we also find a few large pebbles of white quartz, others of a hard, compact, reddish sandstone, of some porphyritic and slate rocks, unlike anything either in the Tertiary or Chalk formations, or in the Lower Greensand*. These pebbles are formed of the Silurian and slate rocks of Wales and the border counties;

* Quartz and other pebbles are found in the Lower Greensand, but they are generally very small and rare.

but although derived originally from those formations, they may be more directly referred to the conglomerates of the New Red Sandstone of Worcestershire and Warwickshire, in which these older pebbles were first imbedded*. But even these strata are not found within a distance of eighty to a hundred miles from London. This indicates a still more remarkable extent of transport than we have hitherto noticed, and one from a different direction. I merely direct your attention to this curious point, which yet remains an open and difficult geological question. Whatever may have been the cause of this exceptional phenomenon, the great and preponderating mass of flint debris from the chalk hills, and of sandstone and chert from the greensand hills of Surrey, leaves no reasonable doubt that the main bulk of the gravel of Clapham and of London has been derived and transported from the Surrey downs and Sussex hills.

Another difficulty may here suggest itself,—What, it may be inquired, has become of the chalk from which all these flints have been derived? for to form a bed of flint gravel 10 feet thick would probably require a mass of chalk 200 or 300 feet thick, the flints occurring only in thin and distant layers, as you may see by inspecting the cliffs near Brighton and at Dover. The explanation of this is, that flints which consist nearly of pure silica (such as rock-crystal), are insoluble in ordinary surface-waters, but as these waters are always impregnated with a certain proportion of carbonic acid gas†, they derive thereby the property of being able to dissolve a small portion of carbonate of lime or chalk. This is so prevalent an action, that, as carbonate of lime is one of the most widely-diffused substances in nature, it is also an ingredient found in almost all waters, whether of spring or river. Thus, when clear, the water from the Thames, that from the spring on the Common, and distilled water, are to the eye exactly alike, and look equally pure and limpid; but if we add to them a small quantity of oxalate of ammonia‡, the Thames water becomes milky and gives a very

* Like the flint-pebbles (fig. 2, p. 10) of the gravel which are referred to the Lower Tertiaries, although derived originally from the Chalk: see p. 16.

† This gas is everywhere present in the atmosphere in the proportion of about 1 part in 1000, and is absorbed by rain, spring, and river waters.

‡ Formed of oxalic acid and ammonia. When a solution of this salt is

visible precipitate, the spring water deposits a still stronger white precipitate, whilst the distilled water remains perfectly clear and without any precipitate. This property of water may, therefore, in the course of time, or else under some unusual conditions, have led to the dissolving away of a large body of chalk, leaving untouched the harder and insoluble flints.

We now come to the second question,—as to the means by which the gravel was formed, or brought into its present position at and around London. We have shown that it is not formed from any rocks on the spot, but that it is derived almost entirely from strata situated at a distance of from six to twenty miles. Therefore it has been transported that distance by some means or other. It is evident that no such operation is at present going on, or has gone on during the historical period, and consequently that the cause, whatever it was, belonged to some past order of things. Geologists agree that such a transport could only have been effected whilst the surface, now covered with gravel, was under water; but, although of one opinion on this starting-point, they differ much as to the mode of operation.

1st. Was it by the sudden and transient action of a body of water, passing rapidly over the surface and sweeping down with irresistible force the debris of the hills of Surrey upon the plain of the valley of the Thames? 2ndly. Or was it by the action of a large river, flowing through Sussex and Surrey and then into the Thames Valley, and bringing down debris or fragments of the rocks over which it passed? 3rdly. Could the ordinary action of sea-currents have scattered the gravel over the surface? 4thly. Or, finally, was the destruction of the Chalk and the strewing of the flints over the surface of the adjacent London Clay the result of ice action and transport by coast-ice and icebergs*? All these views have their advocates.

added to these waters, the ammonia unites with the carbonic acid of the lime, forming carbonate of ammonia, which is soluble and remains dissolved in the water, whilst the oxalic acid unites with the lime, forming an *insoluble* oxalate of lime, which falls down as a white sediment. This is a common test for hard calcareous waters.

* The reasons for believing this great cold to have prevailed here will be given presently (see p. 19).

I will endeavour to put you in possession of the leading facts of the case, so as to enable you to judge of the relative probabilities of the different hypotheses.

To arrive at a correct conclusion we must well examine the physical evidence afforded by the gravel itself. In the first place we must look to see to what amount of wear the stones forming it have been subjected. The bulk of the gravel you will find to consist of pieces of flint stained brown (figs. 2, 4, 5, 6); these, as before shown, are derived from the chalk; but in the chalk they occur in large masses, black inside and white outside; in the gravel, on the contrary, we find them broken and more or less discoloured. You will observe also that they have all lost the sharpness of a newly-fractured flint, and that the edges are worn; still these fragments are worn to a certain moderate extent only,—none of them present any approach to the form of a rounded pebble, like those you find formed by the action of a sea on a beach, such as that at Brighton and Dover.

But besides these subangular fragments of flint, there are found with them black flint-pebbles (fig. 1), which, unlike the former, are most perfectly rounded—not one angle remaining: their form is so regular, their surface so smooth, that it could only have been produced by a very long and constant action of a sea on a shore. Now, it is not possible, that the action which left the greater number of the flints in their rough subangular form, could have formed these round pebbles, or that the action which produced the latter, could have left the other flints so slightly worn*. Whence it is evident, that the two sets of flints could not have received their present form from one and the same action, for if these rounded pebbles had received their form at the gravel period, the whole mass of the gravel must necessarily have been subjected to the same or nearly the same amount

* It may be urged, that on the present shore of a chalk district there are flints in all stages of wear, those just fallen from the cliff being sharp and angular, and those long on the shore being worn down into pebbles. That is true; but in the gravel we find only the two extremes of perfect pebbles and of subangular flints,—the gradation which this view would render indispensable does not exist. The extremes are also greater. In the gravel the flints also are all in fragments: we have no parallel to this on our present chalk shores, and the cause of it is not yet well ascertained.

of wear, and all the fragments of flint comprising it, have become, in like manner, more or less rounded. But if, on the contrary, the action at the gravel period sufficed only to form these scarcely worn, subangular flints, it follows that no other portion of the materials subjected only to the same action, could have suffered a greater amount of wear. We therefore infer that these rounded flints could not have been formed during the gravel period, but must have been worn into that shape at some former period and afterwards introduced into this gravel. Still as these pebbles are formed out of true chalk flints, they must have been derived originally from the chalk.

Let us see whether, in the strata between the gravel and the chalk, we can find beds which will give a clue to the explanation of this fact. The London Clay beneath the gravel consists of a great body of clay, of uniform texture, and without any separate beds of pebbles. Beneath the London Clay, however, is a group of strata known as the "Lower London Tertiaries" (i, Pl. II.), consisting principally of bright-coloured clays and of light-coloured sands, some beds of which are occasionally full of round flint pebbles, without any angular fragments at all, and identical with those found in the superficial gravel. The sea-action which formed them must have been most regular and prolonged for many ages, for every one of the flints is perfectly rounded, even far more so than those of any beach that I know of on the English coast. But how could flint-pebbles from tertiary strata, which in this district are at an average depth of 250 feet beneath the surface, be mixed up with and form part of the surface gravel? The reason of this is, that between this spot and Croydon and Epsom, all the strata here beneath us successively crop out or rise to the surface (see sect. 1. Pl. I.). I have in fact before mentioned that the chalk comes to the surface at those towns, and the strata above the Chalk rise in like manner. You will therefore readily conceive that, as the main mass of the gravel is formed from flints derived directly from the Chalk, and carried by some agency from the chalk-hills of Surrey to Clapham and London, the same denuding* and transporting power would also remove some of the overlying and skirting Lower Tertiary strata, and thus indirectly incor-

* Destruction or wearing down of the rocks on the surface.

porate some of their old flint pebbles in the mass of the more recent gravel*.

By these means we eliminate one conflicting element—the one indicating a great and long-continued wear,—and are left now to deal only with the subangular flints. These, on the contrary, show so little wear, that on no part of our coast, along the line of chalk cliffs, do we find any flint shingle so slightly worn and eroded. Nevertheless, whatever the destructive agency was, it has worn down large surfaces of the chalk and carried the flints to a distance of 6 to 20 miles or more from their parent beds.

In explanation of these facts, the earliest serious hypothesis is that which assumed that the surfaces of the chalk and other strata were torn up and destroyed, the land animals overwhelmed, and the harder debris spread over the face of the country, at one and the same time, and by one cause, viz. the rapid and transient passage of a body of water over that surface†. This agency was considered to have furnished a power adequate to the abrasion and removal of the many hundred feet of solid chalk or other strata which geologists find to be wanting over the face of the whole country. It was argued, that as the action though violent was but of short duration, there would be much breakage and little wear of the uprooted materials; while the absence of contemporaneous marine remains was a natural consequence of the waters resting too short a period on the land to admit of the existence therein of any marine life. With reference to this theory it may be objected, how, if the destruction took place at once and were so rapid, and of so short duration, comes it to pass that such an enormous quantity of material has been so thoroughly removed‡?—and where is it removed to?—

* A similar argument applies to the pebbles of quartz, semicrystalline sandstones, and other old rocks: they were rolled and formed chiefly at the period of the New Red Sandstone, and came into the gravel by denudation of the outcropping surfaces at one of the gravel periods, as first noticed by Dr. Buckland.

† This theory was advocated by Dr. Buckland in his '*Reliquiæ Diluvianæ*,' but was afterwards abandoned by him, and in his later days this eminent geologist warmly supported the so-called Glacial Theory. His original work still, however, possesses great interest from the learning and research it displays, and from the number of valuable facts it contains.

‡ Fig. 19, p. 35, shows the many hundred feet of Tertiary strata wanting in the Thames valley. Also it is probable that the chalk once extended over

why do we not find more debris of the chalk itself in the gravel ? With a sea-action long continued, it is easy to conceive the chalk to have been gradually dissolved, but it is difficult to conceive that dissolution to have been effected so rapidly and so completely as this hypothesis would require. Chalk rubble is, it is true, found in some portions of the gravel near the chalk hills, but it does not spread to any distance. Again, if the action were so violent, how is it that we nevertheless occasionally find in the drift and gravel around London the most delicate and friable land and freshwater shells, perfectly uninjured ? Further, it has been objected against the diluvial theory, that no analogous case in existing nature can be instanced. This last argument I do not, however, think quite valid ; for, although I fully admit that the true and philosophical course in all our inquiries is to endeavour to explain, in all possible cases, past phænomena by causes at present in action, still I hold it to be equally philosophical, in cases where such causes seem inadequate, to judge of what the cause must have been from the results now to be observed, and to derive from those results our conclusions as to what must have been the nature of the forces in former operation. It is not a question as to the identity of the mechanical and physical laws, which we all admit to have been alike and unchanged in all past ages, but one which merely relates to the mode in which those laws were occasionally called into operation by conditions brought on by lapse of time.

Next, with regard to the view of those who assign a fluvatile or river-action origin to the gravel. The supporters of this hypothesis point to the number of instances in which shells, all of fluvatile origin, together with plants, animals, and land shells, such as would be carried down by a river, have been found in the gravel around London. But the gravel, as a whole, seems too widely and irregularly spread and too little worn to have been formed by such means ; nor, though we can understand how a river might transport a considerable amount of debris and wear down and destroy along its course a certain amount of strata, is it easy to imagine so general and extensive a destruction of the greater part of the district (the Weald) between the North and South Downs, from which it has been since removed by denudation.

the chalk and other strata as that which has taken place, to have been caused by so limited a line of action,—supposing the denudation of the country and the formation of the gravel to have been concurrent phenomena.

Thirdly, if the gravel had been spread over the Thames valley by the long-continued action of marine currents, surely we might expect to find somewhere evidences of such a state of things in the existence of those marine remains which so constantly accompany all sea-formed beds. But in this gravel we find no marine remains. Further, the gravel is local, is not worn as if drifted by currents, and is not in regular layers like strata formed quietly in the bed of the sea: it is also constantly separated from the chalk hills by a tract without drift or gravel.

It may, however, be suggested that this having been a glacial period, icebergs or ground-ice formed on the shore, floated out to sea, taking with them annually large masses of the fresh flint-shingle beach, which, as the ice gradually melted, fell to the bottom of the sea, and remained therefore in its original, nearly angular and but little-worn, condition, like the shingle on the ice-bound coast of Greenland*. Here, again, the absence of contemporaneous marine organic remains presents the same difficulty, for seas, though glacial, commonly abound in animal life; whereas most of the gravel is without organic remains, and when they do occur, they are those of land and fresh water. Further, it seems to me that the ice would necessarily have taken up innumerable pieces and blocks of chalk together with the flints; but none such are found in the gravel†.

It may strike you also, that a climate of so arctic a character, as this theory would imply, could not have existed in these latitudes; but this is by no means an impossibility. It is, indeed, rather our present climate which seems the exceptional phenomenon. You will find, on reference to a map, that Great Britain is almost exactly under the same latitude as Labrador—a region of ice and snow. Apparently the chief cause of the remarkable difference between the two climates arises from the action of the great oceanic current known as the Gulf-stream,

* See a paper by Dr. Sutherland in *Quart. Journ. Geol. Soc.* vol. ix. p. 308.

† The same objections apply if we substitute a freshwater lake for a sea, although not all with the same force.

whereby this country is kept constantly encircled with waters warmed by a West-Indian sun. Were it not for this unceasing current from tropical seas, London, instead of its present moderate average winter temperature of 6° above the freezing-point, might for many months annually be icebound by a settled cold of 10° to 30° below that point, and have its pleasant summer months replaced by a season so short as not to allow corn to ripen, and only an alpine vegetation to flourish. Nor are we without evidence afforded by animal life of a greater cold having prevailed in this country at a late geological period. One case in particular occurs within 80 miles of London, at the village of Chillesford*, near Woodbridge, where, in a bed of clayey sand of an age but little (geologically speaking) anterior to the London gravel, I found a few years ago a group of fossil shells, in greater part identical with species now living in the seas of Greenland and of similar latitudes, and which must evidently, from their perfect condition and natural position, have existed in the place in which they are now met with†.

In looking at the problem we have here briefly reviewed, I am inclined to believe that much of the difficulty has arisen from taking the one or the other hypothesis too exclusively, and referring to one cause and to one time that which belongs to many periods and results from many causes. The difficulties of the question, like many others which have often beset our path, will, I trust, be removed by further research and observation. Taking however, in the mean time, into consideration the absence of contemporaneous marine remains, and noting the immense mass of but slightly worn debris derived from and covering irregularly the sedimentary deposits, and the fact that it has evidently been transported from greater or less distances,—combined with the occurrence in the gravel of the remains of large land animals, of trees, and of freshwater and land shells,—we have, I conceive, at all events, in these facts, indications of at least one land-surface here destroyed, and its rocks, plants, and animals involved in one common wreck and ruin. Of the animals of this period we shall have to speak presently.

* Quart. Journ. Geol. Soc. vol. v. p. 345.

† There is other evidence, some of which will be adduced further on. In Scotland the proofs afforded by shells of a great former cold are still stronger.

The third question has reference to the period at which the gravel was formed. This is to be determined in one of two ways,—either by order of superposition, or by the character of the contemporaneous fauna and flora, *i. e.* of the animals and plants which flourished at the period. With regard to the first, we find, at Clapham and London, the gravel reposing directly upon the London Clay, a formation belonging to the earlier part of the tertiary period and of such antiquity, that, with possibly one or two exceptions, all the varied species of reptiles, shells, and plants, which lived at the time it was deposited, are now extinct. We know, however, that gravels similar to that of Clapham, repose elsewhere upon our newest Tertiary strata*, and therefore, that these beds of drift result from one of the latest geological changes which this country has undergone. To determine more exactly the limits of this period, we have to look to the evidence afforded by organic remains, and these furnish us with some of a very singular and satisfactory nature.

The remains of animals and shells which are found, although at distant intervals†, in the gravel of the neighbourhood of London, form a most remarkable and interesting group of fossils, and suggest many curious climatal and geographical questions. The bones of the land animals are sometimes mineralised, but they are far more generally little altered from their original state, except that, having lost their animal matter, they have become soft and fragile, as have also the associated shells. Although the bones are almost always separate‡, they are not much broken or rolled. Each single bone is usually as perfect in form as in recent specimens, so as to admit of the

* Such as the Crag strata of Suffolk and Norfolk, which contain a large proportion of our existing marine shells. (See fig. 18, p. 34.)

† I am not aware that any bones or shells have ever been found in the gravel of Clapham or Wandsworth commons. In the large gravel-pit by the Croydon station, which has been constantly worked for several years, it was, however, not until very lately that a small tusk of an Elephant was found. Yet although these remains are usually so difficult to find, every now and then they are met with in some abundance, as in the gravel at Brentford, in the brick-pits at Clapton and Ilford, in some gravel-pits at Kingsland and Hackney, and in places in the gravel at Westminster.

‡ In a few cases, however, the entire skeleton of the fossil (the elephant more especially) has been found. Jaws, with all the teeth, of the various other animals have been more frequently found.

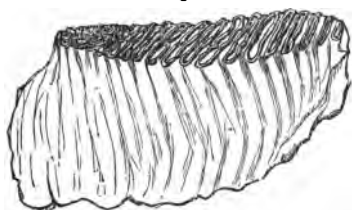
most exact determination; and in the present state of comparative anatomy, and thanks to the wonderful skill and ability of Cuvier, Owen, and others, the results with regard to the relation of the fossil to the recent species may, in all the main points, now be most implicitly relied on.

Amongst the Quadrupeds whose remains have been recognized, we have an Elephant, a two-horned Rhinoceros*, a large animal of the feline tribe related either to the Lion or the Tiger, a large Hippopotamus, a great Bear, a formidable Hyæna, the Red-deer, the Rein-deer, the Wolf, an Ox and a Horse. This must strike you as a very singular group; for, associated with a few animals still common in these latitudes, we here have, on one side, animals of a class now living only in the hot and torrid zones, and, on the other, animals now confined to the cold and frigid zones. To determine their relations and to draw correct inferences with respect to the climatal conditions prevailing during the period at which they lived, are questions requiring extreme caution.

The teeth are more commonly preserved than any other part of the animal, and are more easily determinable. The following are a few outlines of the molar teeth of some of the quadrupeds found in the gravel of the London district.

Remains of Animals of the Gravel or Post-Pliocene Period.

Fig. 7.



Elephas primigenius.
‡ natural size.

Fig. 8.



Rhinoceros tichorhinus.
‡ natural size.

Fig. 9.



Hyæna spelæa.
‡ natural size.

The remains of an Elephant, or the Mammoth (fig. 7), are spread very widely over Europe, its bones, together with those of the Rhinoceros, being often discovered in superficial beds of gravel and drift. Occurring as such fossils do, so near the

* There is another Elephant and Rhinoceros. In the present unsettled state of the inquiry I omit these and a few other animals. See notes, pp. 26 and 29.

surface, and so little altered, their presence has necessarily given rise from time to time to various surmises respecting their origin*.

At present not only is the true character of these bones ascertained, but it is evident that the animals to which they belonged must have lived and flourished in this country even in large herds. A few years since several baskets were filled with the teeth and bones of Elephants of all ages, found in a few square yards of brick-earth near the station at Ipswich. From some railway cuttings through gravel near Westbury, and also near Bedford, several cartloads of the bones of the Elephant and other large animals were removed. Such instances might be multiplied. The Mammoth must have exceeded in bulk any living species of Elephant. Its tusks were also longer in proportion and more curved : some have been found near London from 10 to 12 feet

* These bones in former times were very generally taken for bones of giants, although by some few scientific men their true character was recognized even at an early period ; but, from a want of knowledge of geology, a wrong conclusion was drawn as to the cause of their presence in this country and France. Thus Camden (Gibson's edition of 1722) relates the discovery, in sinking a well at Chartham, near Canterbury, in 1668, and at a depth of about 17 feet, of "a parcel of strange and monstrous bones, together with 4 teeth, perfect and sound, but in a manner turned into stone, each almost as big as the hand of a man. They are supposed, by learned and judicious persons who have seen and considered them, to be the bones of some large marine animal which had perished there, and that the long vale of 20 miles or more through which the river Stour flows, was formerly an arm of the sea ; and lastly, that the sea having by degrees filled up this vale with earth, sand, and other matters, did then cease to discharge itself this way, when it broke through the isthmus between Dover and Calais." The writer then continues : " Another opinion is, that they are the bones of Elephants, abundance of which were brought into Britain by the Emperor Claudius, who landed near Sandwich, and who therefore might probably come this way in his march to the Thames ; the shape and bigness of these teeth agreeing also with a late description of the grinder of an Elephant ; and this depth underground being probably accounted for by the continual washing down of the earth from the hills." A Dr. Cüper expressed his belief that the remains of an Elephant found in Northamptonshire belonged to the identical Elephant brought over to England by Cæsar. But the abundance with which these remains are strewed over the surface, not only of countries visited by the Romans, but of others which they never visited ; the circumstance that they are never found associated with the works or remains of man ; that they are found in ground which has never been artificially disturbed ; and lastly that they belong to species now extinct, form insuperable objections to the view that they are the remains of animals brought over by the Romans.

in length, and even that size has been exceeded by specimens in other parts of England.

Only two species of living Elephants have been described, both inhabitants of tropical climates, the one living in India, and the other in Africa. From the known habits of these animals it was originally inferred that their former presence in England necessarily implied a tropical climate. This, however, is now not only a point of very considerable doubt, but the evidence even points in the other direction. The remains of the Mammoth have not yet been discovered in tropical countries, whereas from the 40th to the 60th degrees of latitude they are abundant. The carcase of the Mammoth discovered entire and so singularly preserved in the frozen ground* forming low cliffs on the banks of the river Lena in Siberia, was covered with long black hair and an undercoat of reddish wool, as though to protect it against the rigour of a climate colder than that in which the Elephant is now generally found, like the small variety of the Elephant seen by Dr. Heber in the cold region of the Himalaya mountains, whose coat of hair he compared to that of "a poodle dog." On the other side, it was objected that the Elephant could live only in countries where trees flourish with a perennial foliage. Professor Owen†, however, arguing from the structure of the teeth and their capability of crushing wood, observed on this point, that, if the animal were properly clothed, like the Rein-deer, it might "have existed as near the Pole as is compatible with the growth of hardy trees and shrubs," for it was "organized to gain its subsistence from the branches or woody fibres of trees," and was "thereby rendered independent of the seasons which regulate the development of leaves and fruit."

A remarkable confirmation of this view has since been afforded by the researches of a Russian naturalist, Dr. Brandt‡, who also observes, speaking of the Mammoth and the Rhinoceros (another animal that might seem to indicate a tropical climate), the

* Not the surface-ground frozen by the annual winter cold, but that ground which at a short depth beneath the surface remains perpetually frozen.

† 'British Fossil Mammals and Birds,'—a popular work of great learning, delightfully expressed, and to which I am indebted for most of my information respecting these old Mammals.

‡ Quart. Journ. Geol. Soc. vol. iv. Part ii. p. 9.

remains of which are found associated in the drift of Siberia, that "the thick covering of hair on both animals shows that a tropical climate was not necessary for their existence." He then proceeds to state that he has been so fortunate as to extract from the cavities of the molar tooth of the Rhinoceros, preserved in the frozen ground of Siberia, a small quantity of its half-chewed food, among which "fragments of pine-leaves and minute portions of wood with a coniferous structure were still recognizable," showing therefore that the animal could find food in the pine forests of those cold regions, and no doubt lived there. Professor Owen's observation, that "it can no longer be regarded as impossible for herds of Mammoths to have obtained subsistence in a country like the southern part of Siberia, where trees abound, notwithstanding that it is covered during a great part of the year with snow, seeing that the leafless state of such trees during even a long and severe Siberian winter, would not necessarily unfit their branches for yielding sustenance to the well-clothed Mammoth," receives from this curious fact corroboration which seems almost decisive. The figure at the end of this lecture (p. 32) shows a restored outline of the *Elephas primigenius* or Mammoth : imagine, however, the hair longer and thicker.

The Rhinoceros (fig. 8) found in the gravel of the valley of the Thames also belongs to an extinct species which seems, like the Great Mammoth, to have been common in northern Europe. This Rhinoceros had two horns like that of Africa, from which however it differed in other respects. Cuvier concluded that it bore longer and more formidable nasal weapons than do any of the known species with two horns. Like the Mammoth, it did not yield in size to any existing Rhinoceros.

The exceeding magnitude of these two animals seems to have been matched by that of the extinct fossil Bear and Hyæna (fig. 9), which must have been, according to Cuvier and Owen, most formidable creatures ; the former equal in size to a large horse ; and the latter much larger than either the recent spotted or striped Hyæna—animals confined to the hotter climates of Africa and Asia. Professor Owen is of opinion that the extinct Bear fed more on vegetables than the existing Grisly Bear does, but no climatal inference can be drawn from its presence, as the living species have so wide a range.

With the Hippopotamus, whose remains have been found, although more rarely, in the London gravel, the case is different. The living species of this large amphibious animal is now entirely confined to the rivers of central and southern Africa, where it lives on roots and other vegetable substances, and is therefore an inhabitant only of the hotter portions of the globe. Still as the fossil species differs from the living one, it may, like the Elephant and the Rhinoceros with which it is found associated, have been so constituted as to bear the rigours of a more northern climate*. The fossil bones of these two latter animals gave no clue to their exceptional woolly covering, and no traces of the hide of the Hippopotamus having been found, we want that direct evidence which in the case of the other two animals has been afforded by the skin and hair actually preserved with the flesh and bones in the manner before named. We can therefore only infer the possibility of a like case, and abstain from concluding, that, because the Hippopotamus inhabits the tropical regions only, its presence at a former period in our latitudes necessarily implies a hot climate.

The same observations apply to another remarkable animal of the drift or gravel period of this country, viz., the great Cave Tiger or Lion, whose remains have been found at Brentford and elsewhere near London. Speaking of this animal, Professor Owen observes, that "it is commonly supposed that the Lion, the Tiger, and the Jaguar are animals peculiarly adapted to a tropical climate. The genus *Felis* (to which these animals belong) is, however, represented by specimens in high northern latitudes, and in all the intermediate countries to the equator." The chief condition necessary for the presence of such animals is an abundance of the vegetable feeding animals. It is thus that the Indian Tiger has been known to follow the herds of Antelope and Deer in the lofty mountains of Himalaya to the verge of perpetual snow, and far into Siberia. "It need not,

* The habits of these animals are, however, such that it is not easy to suppose they could have existed in an extremely cold climate. Dr. Falconer has recently, in a very able paper, endeavoured to show that the Elephant of Grays and Ilford differs from that of other parts of the Thames valley, the true Siberian Mammoth—that the former alone is found associated with the Hippopotamus, and that the two elephants belong to successive and not to contemporaneous periods.—June 1857.

therefore," continues the learned Professor, "excite surprise, that indications should have been discovered in the fossil relics of the ancient mammalian population of Europe, of a large feline animal the contemporary of the Mammoth, of the tichorhine Rhinoceros, and of the gigantic Cave Bear and Hyæna, and the slayer of the oxen, deer, and equine quadrupeds that so abounded during the same epoch." The dimensions of this extinct animal equals that of the largest African Lion, or Bengal Tiger, and some bones have been found which seem to imply that it had even more powerful limbs and larger paws.

With the Elephant and Rhinoceros, whose living analogues are more restricted to warm and sunny regions, are however associated others of a diametrically opposite character: these are the Aurochs (or Bison of the ancients), and the Reindeer, whose range is confined to the north temperate and glacial parts of Europe and Asia. The climatal evidence afforded by the fossil bones of these animals, is the more valuable, inasmuch as they are not distinguishable from those of the living species. The Reindeer (fig. 11) still flourishes in the arctic regions; whilst the Aurochs (fig. 12), common at the time of the Romans in the extensive forests of Germany and Belgium, is now confined to a few of the forests of the Russian empire, where "it survives only by virtue of strict protective laws."*

Lastly, with these classes of animals, now denizens of other latitudes, there are found some others still common in our own temperate climate, such as the Red Deer (fig. 10), an Ox, a Horse, and a Wolf.

The fossil remains of the Red Deer (fig. 10) are not distinguishable from those of the living species, which abounded in the forests of England until the 16th century, and which still roams in a wild state on some of the mountains of Scotland. The Ox belongs to an extinct species, characterized by its short horns, and was in size equal to our ordinary cattle. The fossil horse is also of an extinct species, and its height was that of a middle-

* Since the delivery of this lecture, the fossil skull of a musk-ox, which Professor Owen has identified with the recent species, has been found by Mr. J. Lubbock, in the gravel at Maidenhead. This animal is one peculiarly of an arctic character, living in the most northern parts of America, and not roaming south of about 60° of latitude. Quart. Journ. Geol. Soc. vol. xii. p. 124.

sized horse. "It differs," says Professor Owen, "from the existing domestic horse in its larger proportional head and jaws, resembling in that respect the Wild Horse."

Remains of Animals of the Gravel Period.

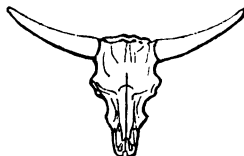
Fig. 10.



Fig. 11.



Fig. 12.



Cervus Elaphus.

Cervus tarandus (restored).

Bison priscus.

[These horns are of about the size of those of the living species.]

These are some of the principal animals which flourished during this late geological period: they belong to families now widely dispersed and severally confined to various latitudes, from the tropics to the torrid zone, but then fitted to inhabit a common land. It is a singular fact, that whereas the larger number of these great animals have been swept away and their species have become extinct, a large proportion of the friable and delicate shells, which then frequented the land and rivers of the same countries, have lived through the various geological changes which have since succeeded and exist at the present day. The testacea, in fact, of that past period are for the greater part identical with our present indigenous fluviatile and terrestrial shells. Such are the delicate and fragile *Pisidium*

Shells of the Gravel Period.

Fig. 13.



Fig. 14.



Fig. 15.



Fig. 16.



Pisidium amnicum.

Planorbis spirorbis.

Pupa marginata.

Succinea oblonga.

[All of natural size except fig. 15, which is considerably enlarged.]

amnicum (fig. 13), and *Cyclas cornea*, *Bithynia impura*, the *Succi-*

nea oblonga (fig. 16), *Limnaeus auricularis*, *Planorbis spirorbis* (fig. 14), which now abound in the Thames, the Wandle, and the ponds and rivers of this very district; and amongst the land shells several small species of *Helix* (snails) and the *Pupa marginata* (fig. 15) of the gravel period still live on the commons and heaths of this and other parts of the neighbourhood of London; whilst a freshwater Mussel (*Anodonta cygneus*) is also common in the streams and canals around London*. These small creatures have withstood the lapse of time and the geological changes that have annihilated their gigantic contemporaries, and they thus serve to connect the present with the past, and aid to guide us from the known conditions of the present world to the discovery of the unknown ones of those of the world gone by. We have therefore to ascertain what extent of range these old pond and river shells now have, and how they are affected by temperature. Some will be found to have their chief development in temperate, and others in cold climates; a small number range throughout the greater part of Europe, and a few extend even to the north of Africa. Although some of these shells might live in a climate warmer than that of England, still, looking at the entire group, they are such rather as we might expect to find in a colder than in a warmer climate than our own. Taking this evidence in conjunction with that before brought forward with respect to the various animals, it is probable that, notwithstanding the tropical forms of many of them, the temperature of this part of Europe, at the time these great mammals flourished here, may not only have been no higher than at present, but that the cold of winter at all events may have been far more severe, resembling in that respect an arctic rather than a temperate region†. Still this question cannot yet be regarded as thoroughly settled.

Lastly, we have to consider the third question we originally proposed, and which we are now in a position to judge of ap-

* It is possible that it may become necessary to separate the shells and mammals, which I have here taken altogether, into two or more groups, a portion of each belonging to two nearly related but still successive stages, both, however, included in the so-called Drift period.

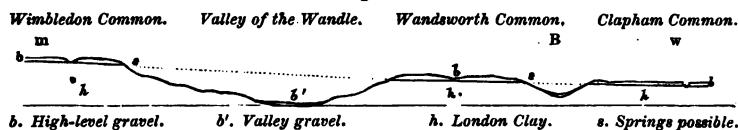
† In some parts of the kingdom it is considered that the surface of the rocks shows traces of ice- or glacial action.

proximately, viz. "At what period was the gravel spread over the surface of Clapham and Wandsworth Commons, and adjacent London district?" Almost all the forms of animal life which existed at the time of the formation of the older tertiary strata (*g*, *h*, *i*, Pl. I.) are now extinct, so that the period of their accumulation is removed to an immeasurable distance from our time*; but with regard to the remains found in the gravel, we have seen that several species of the animals and almost all the shells still exist, which renders it evident that the gravel is, geologically speaking, of recent date. Geologists place it in the period termed Post-Pliocene†, *i. e.* class it amongst the latest geological changes which have taken place on the globe.

But although so comparatively recent, the gravel was spread over this common before the land had quite assumed its present configuration. Let us examine the surface between this spot and Wimbledon (fig. 17). In crossing the common, you will

*Section from the Spring-well (°) on Clapham Common to the
Windmill (™) on Wimbledon Common.*

Fig. 17.



find that the gravel is continuous, and occupies nearly the same level; but, on arriving at the brow of the hill looking towards Wandsworth Common, you will remark that it ends suddenly, and is succeeded by clay, *h*,—the same which lies under it on this Common,—and which continues down that hill and up the slope of the next; but when we reach the summit at Wandsworth Common, we again meet with the same bed of gravel, *b*. In descending the hill into the valley of the Wandle, the clay, *h*, is again found on the surface and up the opposite slope of

* It is a well-established truth in geology, that, as we go backward into past times, species now living become more and more scarce until they are no longer found; at the same time species are met with which are now extinct, and these become more and more numerous the further we recede from the present time, until at last they alone are met with, and all existing forms, both of the animal and vegetable world, are absent.

† Signifying—*after the more recent.*

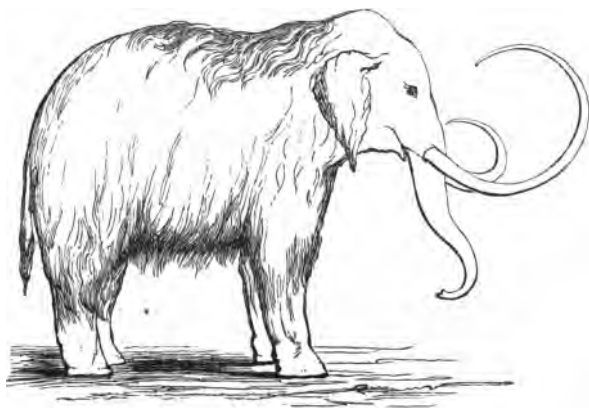
Wimbledon Hill, on the top of which the gravel reappears. But in addition to this, there is another bed of gravel at the bottom of the Wandle valley, *b'**, which I believe to be of a different age to that on the Commons†. For the observations we have just taken show you that the higher-level gravel, *b*, is cut off abruptly on the slopes of each valley, in a way that could not be if this gravel had been spread over the district after the hills and valleys had assumed their present form. Had it been so, the great bulk of the gravel would necessarily have settled in the valleys, and would thence have extended in decreasing thickness up the slopes of the hills, and been scattered more sparingly on their tops; whereas the great mass of the gravel has lodged on those higher and flat levels, leaving the valleys comparatively bare. Further, as the gravels on Clapham, Wandsworth, and Wimbledon Commons, are alike in composition and on the same plane, it follows that they probably had the same origin, and were once continuous, as indicated by the dotted line; and it must have been after the gravel, *b*, had been spread, that the valleys of Battersea Brook and of the Wandle were excavated and formed as we now see them. Consequently these valleys and the gravel, *b'*, in them are of more recent date than the gravel, *b*, on the Commons: the difference of level between the two amounts to as much as 60 and 150 feet. How the excavation of these valleys, and the greater one of the same nature described at p. 35, were accomplished, involves an important and open geological problem. Various are the theories which have been suggested, but it will suffice for our purpose to establish the simple fact, which is of much interest, that it was at a very recent geological period that the surface of the land in the neighbourhood of London received its final configuration and outline. It was one of the last changes which preceded the present order of things. It took place, in fact, at a time when many species, yet living, had made their appearance on the earth, and when many other living species were then represented by closely-allied extinct analogues; an epoch like to our own in many of its forms of life, but different in its conditions of temperature, in the distribution

* And traces of it probably along the slight valley of Battersea Brook (B).

† Not that I consider them far separated in age: they show, however, different stages in this drift period.

of land and water, and especially distinct in the associations presented in the animal world.

Such briefly are some of the leading phenomena connected with the gravels of Clapham and London. The subject relates to one of the last chapters in the earth's history, and is one which, owing to the very fragmentary and superficial character of the materials with which we have to deal, yet remains one of the most debateable and unsettled in geological science. I could have said much more on this question, of which I have necessarily given only a short and imperfect sketch; but the few main facts I have stated to you, will, I hope, be sufficient to show that, notwithstanding the veil thrown over the earth by its present beautiful surface, there are immediately beneath it the wrecks of past surfaces (only the first of which we have described), that, from the slight glimpses we can obtain of them, would seem to have been equally full of interest and equally wonderful—the presence of man alone excepted.



SECOND LECTURE.

EOCENE PERIOD.

THE LONDON CLAY,—ITS STRUCTURE, AGE, AND ORGANIC REMAINS. (*h*, Pl. II.)

IN my last Lecture I directed your attention solely to the phenomena connected with the gravel beds, or “drift,” one of which forms the upper surface of the ground on this Common. We will now pass on from the irregular superficial deposits to the older, regular, and more important strata, which here and at London lie beneath them. In this part of the subject we shall have to deal with an entirely different set of phenomena, and to treat of a period differing far more widely from our own than the one just described.

Immediately under the gravel, and at a depth varying from 3 to 12 feet, you will find a tenacious brown and blueish clay. This is known as the London Clay,—a peculiar argillaceous formation extending West and East from Newbury to Harwich, and North and South from Hertford to Croydon. Although we here pass at once from the gravel to the London Clay, you must not suppose that the latter immediately precedes the former in order of time. A vast interval separates the two deposits, an interval so great, that not a single species of any of the animals, shells, or fishes common during one period, existed during the other.* We have, however, other evidence for this assertion than the great dissimilarity of organic remains, for elsewhere, between the gravel and the London Clay, a number of other strata are found, forming a series many hundred feet thick. Thus the sand-hills of Bagshot, Esher, and Chobham, the limestones of the north side of the Isle of Wight, and the Crag of the eastern counties, are newer than this London Clay, but older than the gravel, which, at places, lies indifferently upon all these strata.

* With the doubtful exception of one shell.

Fig. 18, in which the relative proportions of these formations are approximately stated, will give you some idea of the great

Fig. 18.

<i>Approximate thickness.</i>	<i>Order of succession*.</i>
?	<i>b</i> Post-pliocene drifts and gravels.
80 ?	<i>c</i> Crags of Norfolk and Suffolk.
700 ft.	<i>f</i> Fluvio-marine series of the Isle of Wight.
600 ft.	<i>g</i> { Barton and Bracklesham series of Hampshire; Bagshot Sands of Surrey.
450 ft.	<i>h</i> London Clay.
150 ft.	<i>i</i> Lower London Tertiaries.
A	


The perpendicular line, A, gives the measure of the strata existing within 12 miles of London. The portion up which this line is not carried is wanting.



mass of strata here wanting†. All these formations are nowhere found in complete succession; at some places one deposit, and at other places other deposits are wanting, but the order of succession is never reversed. There is every reason to believe that all, or at all events, a large portion of the Bagshot Sands, at one period extended above Clapham and London. Not only, however, have all these strata, except mere fragments, been swept away, but of the London Clay itself only a portion remains. Just here this latter formation varies in thickness from about 160 to 220 feet, whereas in its normal condition, or where fully developed and intact, it measures from 400 to 500 feet. This is not a variation caused by the irregular accumulation of the sea sediment of which it is formed, but arises, as I will show you, from denudation, or the removal of part of the original strata.

To understand this, we will first turn to Hampstead. There, from well-sections, the London Clay has been ascertained to be

* For a description of *f*, see the posthumous monograph of the late deeply lamented Professor Forbes 'On the Isle of Wight Tertiaries,' recently published by the Geological Survey; *b* and *c* have been described in various papers by Woodward, Charlesworth, Trimmer, J. Brown, Searles Wood, Sir Charles Lyell, and Godwin-Austen.

† Even this series is in itself incomplete. Between *c* and *f* there is a group of strata largely developed on the Continent, but wanting in England.

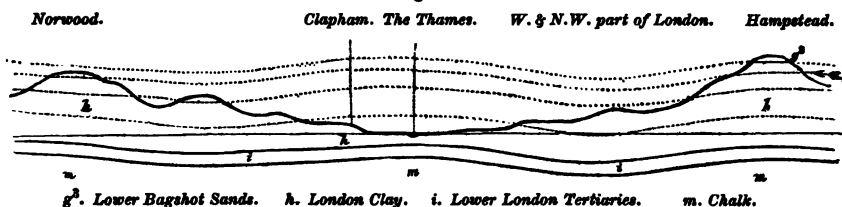
about 420 feet thick ; and we know we have reached the top of it because it is overlaid by the strata next in order of succession, viz., the Bagshot Sands (g^s , fig. 19), which is dug in pits on the top of the hill. Now, the London Clay consists of beds which lie horizontally one over the other. If Hampstead Hill had been formed by a local elevation from beneath, the strata would be curved  ; or, if by sediment thrown down on that

spot only, they would overlap and thin out  : but neither is the case ; the strata are horizontal, and, as it were, cut off on the sides of the hill  . Turning

southward to the Norwood hills, there also we find the strata horizontal, and the London Clay, as proved by the well at the Crystal Palace*, is about 380 feet thick. We thus have two places, eleven miles apart, of which the underground structure is determined : let us now connect them, taking Clapham, which lies nearly on the line between the two, on our way.

Section across the Thames Valley from Hampstead to Norwood.

Fig. 19.



We first have to note that Hampstead Hill rises 430 feet above the Thames, that Norwood Hill is 353 feet above that level, and Clapham Common from 60 to 90 feet only. At Norwood and Hampstead, the London Clay is underlaid by a bed of rolled flint pebbles or of sand (i^1 , Pl. II.) ; in sinking deep wells at any and all intermediate places, as at Paddington and Westminster, the same beds have been reached at certain known depths ; and if we connect these several points, we shall be furnished with a base-line of like character throughout. The London Clay generally is so much alike all through its mass, that we can rarely trace sufficient difference of mineral character to recognize par-

* Taking into account the height of the hill above the mouth of the well.

ticular strata. There is, however, a very sandy bed (— fig. 19) a few feet thick, about 100 feet beneath the top of the clay at Highgate and Hampstead, and which occurs also very near the summit of Norwood Hill. This, from its unusual occurrence, is sufficiently distinctive to give us another horizon. As the Bagshot Sands do not commence until we get 100 feet above this level, the Norwood hills are not quite high enough to retain any portion of them. I shall hereafter give you a more particular account of the distribution of the organic remains in the London Clay; but I may here remark, that if we divide this formation into four zones*, we shall find each of them characterized by few peculiar species, or by a large development of particular species. Thus at the Archway, near the top of Highgate Hill, and again on the same level at Hampstead, a certain group of shells is found. In excavating for the terminus of the Crystal Palace Railway, a number of shells were found which apparently belong to the same set. Another zone includes the strata at Wandsworth Common, and at Primrose Hill. It is characterized by the occurrence of the *Pholodomya margaritacea* and *Cardium semigranulatum*, both of which shells were found rather commonly in cutting the railways through these places. The lowest zone is still better marked by a small but definite group of fossils often very abundant at the base of the formation.

Such observations furnish us with a number of recognized points which we can now connect by lines parallel with the base of the clay, in the way in which we presume the strata to have been originally formed. The result (fig. 19) shows that the Hampstead and Norwood hills are but truncated and isolated portions of a great mass of stratified clay, which at one time also occupied the intervening lower space in which Clapham and London now stand. All this has been swept away, together probably with a portion of the Bagshot Sands, from the spot where we now are, before the period when the gravel of the Thames valley was accumulated. What great and singular changes this fact indicates! Here are thick masses of strata necessarily requiring for their formation a very long period of time; and then followed, after a long interval, another period,

* These are roughly indicated by the dotted lines in fig. 19.

during which part of the previous work was undone, and many of its records destroyed. Of the original geological monument, recording the life and work of many long ages, a portion only is preserved; but that portion is sufficient to certify to their reality, and to indicate the order and character of the successive phenomena of that bygone period. Of the original 400 feet or more of London clay, there now remains at Clapham and London, where it constitutes the substratum of the ground, an average of only about 200 feet. In its material aspect it offers no cause for notice; we however have to view the remaining strata of this formation as the tablets on which the lengthened passage of time and the fleeting passage of the life of that time is recorded; and they are then found to possess a peculiar importance, to which at first sight their unpromising appearance would certainly fail to show a claim.

In treating of a mass of strata such as that forming the London Clay, we may consider it under five principal heads. 1st. We have to look at it in relation to the other masses of strata which lie above and beneath it, so as to determine what is called its order of superposition and its age relatively to the other formations of the country. Thus the London Clay always overlies the Chalk, and underlies the Bagshot Sands, wherever they are found in juxtaposition; and the London Clay is therefore said to be newer than the Chalk and older than the Bagshot Sands.

But its more exact age hinges rather on the 2nd consideration, which consists in ascertaining the character and sort of animals and plants which flourished during the period at which the formation was accumulated. We have to determine how far these fossil remains assimilate to, or differ from, existing nature,—to picture to ourselves the life-world which then flourished under these skies,—to study the relation of all its parts,—and to trace its analogy with the living things now peopling the earth. When we have thus determined the character of the animals and plants living at any particular period, then by comparing them with those now living, and with those which have lived in other past times, we ascertain the relative period of the world's history in which the group under examination may have flourished, and we are by this means able to assign approximately to any parti-

cular formation its chronological place in the earth's history. This study is full of interest, both from the novelty of the new world to which it introduces us, and from the endless and marvellous variety it exhibits in the works of Creation. Time illimitable, and a boundless skill and wisdom, of which our deepest researches only give us some faint idea—for, instead of appearing to come to an end, the prospect on the contrary continually enlarges as we proceed, and, step by step, slowly extends the sphere of our knowledge—are as apparent in the records of the past as of the present. This past shows us these attributes of infinite power in operation as unceasing and immeasurable then as now.

3rdly. We must note the thickness of the strata and the number and extent of the successive zones of animal life, so as to arrive at some estimate of the length of time which may have been required for the accumulation of such a mass of sediment, and for the growth, life, and succession, of the tribes of creatures whose remains we find in a fossil state; but this we can only do relatively and without any attempt to a close approximation.

4thly. We must study the description of animals and plants, and the character and arrangement of the sediment, so as to form some opinion as to the probable nature of the climate, the depth of the seas, and the position of the land and water at that period of time.

And 5thly, we must examine the mineral character and structure of the mass, and see, as it were, how it is built up, so as to ascertain whence the materials of which it is formed were derived, and to judge of the forces in operation during its formation and of those which have since acted upon it.

By inquiries of this nature we endeavour to arrive at some approximate conclusion as to what may have been the appearance of our globe at different periods of its history, what creatures roamed over its dry lands, and what were the inhabitants of its waters. We determine also, as nearly as we can, what was the distribution of land and water at each time, and what physical changes the surface may have undergone. To accomplish these objects it is necessary not only to collect the peculiar and characteristic fossils of each period, but to observe likewise all the phænomena which may tend to throw light upon the general

physical questions; and to do this rightly and successfully, we must not only note the grander features and more curious details, but we must not neglect any of the smaller links and facts, though they may appear comparatively trifling, that bear upon these subjects. In the limits of this lecture I cannot touch upon all the foregoing questions. I must give greater prominence to some than to others. Some, such as the effects of disturbances and faults in the strata, I must omit altogether.

With respect to the order of superposition. It is readily determined by pits, wells, and railway sections, that the London Clay overlies certain beds of sand, and that these rest on the chalk; whilst we find that at Hampstead, Harrow and Weybridge hills, it is covered by another mass of sands known as the Bagshot Sands. No other strata occur above these latter in the London district, but in the Isle of Wight we find them overlaid by the whole of the fluvio-marine series of Headon Hill, Cowes, and Ryde (fig. 18, p. 34). Therefore it appears that the London Clay is placed low down in a certain series of strata, which we call the Tertiary series*. It belongs to that lowest portion of them known to geologists as the Eocene† division. The meaning of this word is, that it was the dawn of the present system of things; and, when originally used, it was intended to imply that we then first discover some of the same species of living things as those which exist at this day. It is now indeed questionable whether this be actually the fact; for, as I shall presently repeat, none of the species (with one doubtful exception) of the fossils of the London Clay are now identified with species yet living—nevertheless it is indisputable that at that period, although we may not have identical species, still we meet with the first appearance of a large portion of the ordinary genera and classes of plants and animals, which now flourish on the earth; therefore the term is in the general sense true and appropriate.

The Organic Remains of the London Clay are of much variety and interest. Some portions of this formation contain

* All the sedimentary strata were originally divided,—1st, into the oldest or *primary*; 2nd, the next above, the *secondary*; and 3rd, the newest or *tertiary*.

† Gr. *Dawn-recent*.

them in abundance, but it is more frequently difficult to find any, and many of the strata seem unfossiliferous. In this immediate district, as there are no open pits or sections, and so many of the zones are wanting, it is rarely that an opportunity of obtaining any fossils occurs*. We must therefore study them where the Formation is more complete and better exposed, and where its fossil contents have been well explored, as in the cliffs of Herne Bay and of the Isle of Sheppy, at Highgate Archway, and in various railway cuttings. Examined thus generally, we shall find that the London Clay contains a very remarkable group of organic remains; we shall find an ancient world with indications of great completeness in all its parts, allowing of course for the absence of those soft and perishable forms which are not likely to be preserved in a fossil state.

* The only fossils we know of in this district are those which were obtained when the railway was made over Wandsworth Common; there are:—

<i>Bivalve shells.</i>	<i>Univalve shells.</i>
<i>Astarte rugata.</i>	<i>Cassidaria nodosa.</i>
<i>Avicula media.</i>	<i>Conus concinnus?</i>
<i>Cardita.</i>	<i>Dentalium.</i>
<i>Cardium semigranulatum.</i>	<i>Fusus trilineatus.</i>
<i>Corbula globosa.</i>	<i>Natica glaucinoides.</i>
<i>Cyprina planata.</i>	—— <i>labellata?</i>
<i>Modiola elegans.</i>	<i>Pleurotoma terebralis?</i>
<i>Nucula amygdaloides.</i>	<i>Pyrula tricostrata.</i>
<i>Pectunculus decussatus.</i>	<i>Rostellaria macroptera.</i>
<i>Pinna affinis.</i>	—— <i>lucida.</i>
<i>Pholadomya margaritacea.</i>	<i>Solarium patulum.</i>
<i>Syndosmya splendens?</i>	<i>Voluta denudata?</i>
<i>Chambered Shells</i>	<i>Nautilus imperialis.</i>
<i>Crustaceans</i>	<i>Zanthopsis Leachii.</i>
<i>Corals</i>	<i>A Turbinolia.</i>
<i>Fishes</i>	Vertebrae and teeth of Sharks.
<i>Plants</i>	Wood, often pierced by the Tereido.

These are principally taken from Dr. Mantell's list, *op. cit.* p. 135.

For a complete enumeration of the fossils of the Tertiary strata, and also of the drift period, I would refer to Mr. Morris's 'Catalogue of British Fossils.' I have likewise given a list of the London Clay fossils in *Quart. Journ. Geol. Soc.* vol. x. p. 410. The finest collection of Highgate Fossils is that of Mr. N. T. Wetherell, and of Sheppy Fossils that of Mr. J. S. Bowerbank.

Foraminifera *.—These, to begin with the most simply organized and at the same time the smallest creatures, are amongst the most minute and obscure of any now living in the seas, in many of which they swarm and form the food of numerous molluscs and fishes. They are mostly microscopic, though some attain the size of a grain of corn and a few species are as large as wafers. They are also occasionally extremely abundant in a fossil state, but in the London Clay they had been rarely found until Mr. Wetherell, and more recently Mr. Rupert Jones, detected them in considerable abundance in some particular beds of clay at Highgate and at Copenhagen Fields, rather above the level of the clay here. We now know of 15 genera in the London Clay, of which the *Rotalina* (fig. 21) and the *Nodosaria* (fig. 20) afford the greatest number of species. These little creatures have long been a puzzle to the naturalist. Many of them are in shape exactly like the most elegant diminutive shells, and they were therefore associated with Molluscs; but they are now found to have no relation with shells,—they are considered to belong to a far lower order of animals—to be closely allied to some of the Infusoria and a little in advance of the Sponges.

Foraminifera and Corals of the London Clay Period.

Fig. 20.



Nodosaria.
Bacillum (var.).

Fig. 21.



Rotalina.
Soldanii (var.).

Fig. 22.



Websteria
crisioides.

Fig. 23.



Paracaryophyllus
caryophyllus.

Figs. 20 & 21 are largely magnified drawings, the actual size of the specimens being represented in the small spots to the left of the figures. Figs. 22 & 23 are of the natural size.

Zoophytes† or Corals come next in order of importance. Of these, 10 species, all extinct, are found in the London Clay. They belong to the smaller single forms of Corals—not to those which build up coral reefs. Amongst them are the *Paracarya-*

* From two Latin words, signifying *hole-bearing*, indicative of the general perforation of their shells, internally and externally, with minute holes.

† From two Greek words, signifying *Animal-plant*, i. e., creatures raising a common habitation, branching in form like a plant.

thus (fig. 23), of which 2 species are found at Sheppy, and the *Websteria* (fig. 22), from Haverstock Hill, Hampstead Road. Altogether corals are comparatively rare fossils in the London Clay, a result which might almost be anticipated, as corals seek clear water and a sandy bed; few, in fact, will live except in the most limpid waters; and you may therefore readily conceive that a sea in which such a great clay deposit was accumulating, was not favourable for their existence.

The Echinodermata*, or the Star-fishes and Sea-urchins, follow. Of these there are, in the London Clay, 17 species, belonging to 8 genera. These are few, compared to the number living in the present seas, from which all these fossil species differ. This class of animals is mostly found in rather deep water. Of the Sea-urchins, a family common in the oldest times and abundant now, one of the principal species of the London Clay is the *Cælopleurus Wetherellii* (fig. 25): it is very plentiful at Sheppy. Of Star-fishes the remains are much more rare. There is one very elegant form, the *Ophiura Wetherellii* (fig. 24), which had hitherto been considered a rare fossil; but a short time since Mr. Wetherell found at Highgate a *Septaria*†, 2 or 3 feet in diameter, of which the surface was literally covered with hundreds of these delicate radiated creatures in a fossil state: they must have swarmed at that place.

Sea-Urchins and Crustaceans of the London Clay Period.

Fig. 24.

Fig. 25.

Fig. 26.

Fig. 27.



Ophiura
Wetherellii.

Cælopleurus
Wetherellii.

Zanthopsis
Leachii.

Hoploparia
Bellii?

Fig. 24 is usually larger; and Fig. 25 smaller. Figs. 26 and 27 are greatly reduced.

The Crustacea ‡, or such Shell-fish as Crabs, Lobsters, Shrimps,

* Gr. *Hedgehog-skin*; i. e. with a surface covered with spines.

† A large more or less flattened argillo-calcareous nodule, with the inside broken up by divisions or septa. Cement-stones of the manufacturer. They are found in layers in the London Clay.

‡ Lat. *A shell or a crust*, i. e. creatures with limbs cased in calcareous close-fitting, jointed coverings.

and allied genera, are abundant in some portions of the London Clay. They are amongst the commonest and at the same time the most curious of the fossils at Sheppy. Although so numerous, they have yet been but little studied, only 8 species having been described. One very common species of Crab is the *Zanthopsis Leachii* (fig. 26). We have also a variety of Lobster (fig. 27), and a creature resembling a gigantic Shrimp or Prawn. If to these we add the undescribed species, the number of the so-called fossil Crabs will amount to at least 14, and of the large lobster-like shell-fish to 8.

On our coasts at present only 34 varieties of crab, 3 species of lobster, and 6 of the shrimp tribe are known. The fossil species of the London Clay belong to 4 genera; not only are all the species of these genera extinct, but the genera themselves no longer exist, although some of them approach, as in fig. 26, very closely to the forms of some recent Crabs.

Shells.—The next group of animal life are the Testacea or Mollusca*. These always form an important feature in geological researches in consequence of the calcareous shells of these creatures being amongst the most readily and constantly preserved of all animal remains; and from the preponderance of mollusca at all periods of the earth's history since life appeared on the surface. They are therefore amongst the surest and best guides we possess for the comparative study of the different formations. The London Clay is far from being so rich in fossil shells as many other deposits, like the Chalk, or the Tertiary strata in France, which contain less clay and more calcareous matter. The London Clay, as a sea-bed, was not so favourable to their existence, nor, as a matrix, was it so well suited for their preservation. The greater part of the fossil shells of Sheppy are in the state of pyritous casts, *i. e.* the interior of the shell has been filled up with iron pyrites†, which has formed a solid and exact cast of the interior, whilst the shelly matter is in most cases decayed and often wanting. At Southend the shelly matter is better preserved; but it is at

* The one name is derived from the outer covering, the shell, *testa*; and the other from the body of the animal—*mollis*, soft, pulpy.

† Consisting of iron 1 part, sulphur 2 parts.

Highgate (near the Archway) that the best-preserved specimens of shells have been obtained.

The collection, although not large, is interesting, from the peculiar and marked character of many of the species. The total number of described species is 220. Of these there are 138 univalves, 72 bivalves, and 10 chambered shells.

Amongst the most remarkable of the latter is the *Nautilus*, a genus of shells, none of which now live in the British seas. There are in fact only two living species known, and they inhabit the seas of China and India, and the Persian Gulf. Yet, at the period of the London Clay, there existed at this spot, or within the distance of a few miles, vast numbers of these fine shells belonging to no less than 7 species. In their fossil state they in fact now form one of the commoner London Clay fossils. The one figured at page 46 is a species which has been found at Wandsworth Common, Brentford, and Highgate.

The bivalve shells also present many singular features. There are species of some genera which bear a close resemblance to some found on our own coast, such as those of the *Mussel*, the *Oyster*, and others. There are other genera again, the species of which are not now so abundant in the British seas as they were at the time of the formation of the London Clay, but are now more common on the shores of Norway and of North America, such as the *Cyprina*, *Astarte*, &c. More numerous are those which at the present time are either not found on our own coasts, or else have their chief development in more southern seas; amongst these are the *Pectunculus*, the remains of which exist in thousands at Highgate, but of which the majority of the recent species live in the seas of the West and East Indies, New Zealand, and Western America; the *Pholadomya* (fig. 29), of which three are there species in the London Clay, a shell now confined to a single species inhabiting the seas of the West Indies; the *Lingula* now living on the coast of India, the Philippine Islands, Australia and the Sandwich Islands. Many other species have the same southern facies, but these few will suffice to give you a general idea of this leading fact.

There is, however, one more bivalve so unlike its fellows that I must give you a short account of it, especially as it appears to

have swarmed in the waters of the old London Clay sea. You may often have seen on the coast pieces of ship timber eaten into in all directions by worm-like cavities. This is done by a small creature commonly called the Ship-worm. All timber exposed to the sea is very liable to its attacks. A few years since the bridge at Teignmouth was completely undermined by it; the pier at Herne Bay had many of its piles utterly destroyed; whilst in Holland the evil was at one time so great, that in 1733 serious fears were felt lest the foundation piles of the towns and the piles supporting the dykes should, owing to the ravages of these small creatures, give way. Naturalists and politicians wrote about them, described them, and advised what should be done. One monograph alone occupied 360 pages, a circumstance which led a late distinguished naturalist to observe that "Holland was then seriously threatened by the boring of this little shell-fish and Dutchmen by that of its biographers." Up to that time the nature of the creature which committed these ravages was not understood. The inquiry then set on foot led at all events to its true character being determined, and instead of being a worm, it was found to be a boring bivalve shell, with a tube attached to one end of it, varying in shape and length as the animal penetrates into the interior of the wood. It not only attacks ships and piles, but also fixes on trunks of trees, ship-timbers, or other wood floating in the sea. In the latter case its operations are often useful in breaking up and destroying many large masses of wood, which might otherwise, at times, obstruct the navigation of small craft. It was long imagined that the ship-worm was introduced into this part of Europe about two centuries since, by vessels returning from more southern seas where it abounded; but later researches have refuted this popular impression, and show that it has been met with on these coasts for many centuries past*. Far older, indeed, do geologists now prove it to be in these latitudes. The London Clay contains a quantity of fossil wood, a large proportion of which has been traversed through and through by these little animals, as though all such fragments of wood had, as now so commonly occurs at the entrance of all rivers, floated out into these old seas and been

* This account is abridged from Forbes and Hanley's very valuable "History of British Mollusca."

subjected to the like attacks of this destructive little animal. A few years since I found the prostrate fossil trunk of a tree, 40 ft. long, imbedded in the London Clay near Strathfieldsaye in Berkshire, the whole of the under-side of which was thickly studded with the holes of these old sea-worms.

The univalve shells exhibit results very similar to those presented by the bivalves. We find amongst them the same admixture of genera, some now commonly frequenting our own coasts, a few ranging northward to Norway and even the colder seas of the north; whilst a still larger number are now either confined in their range to more southern seas, or else have their greatest development there, as the *Cassidaria* in the Mediterranean; the *Rostellaria* in the Red Sea, Borneo, and China; the *Pyrula* to Australia, Ceylon, and the West Indies; the *Conus* (fig. 30) (Cone shell) found in all tropical seas; the *Voluta* (most abundant at Highgate), in the seas of China, Java, and the West Indies; and the *Cypræa* (or Cowry) on the coast of Africa*.

Thus almost all the genera of shells of the London Clay are still found in some parts of the present world, although very widely dispersed through all latitudes and all climates. It is different, however, with the species of these genera. All, with one doubtful exception, differ in some way or other from those now living. They are all extinct species. The difference may be often slight, but it is marked and well maintained.

Shells of the London Clay Period.

Fig. 28.



*Nautilus
imperialis.*
½ Nat. size.

Fig. 29.



*Pholadomya
virgulosa.*
½ Nat. size.

Fig. 30.



*Conus
concinnus.*
½ Nat. size.

Fig. 31.



*Fusus
coniferus.*
½ Nat. size.

* For by far the best account we have of the geographical distribution of the Mollusca see Mr. Woodward's more-than-rudimentary "Rudimentary Treatise of Recent and Fossil Shells;" J. Weale, 1850;—a little work without pretension, but of great merit, comprehensiveness, and originality.

Fishes.—With the exception of the beautifully preserved fossils of Monte Bolca, the London Clay presents the largest and finest group of fishes of any of the European Tertiary strata. The whole of the British seas, extended as the coast is, and presenting so great a variety of temperature, depth, and feeding-ground, contain only 163 species of fish; whilst, if we take any one sea separately, such as the English Channel, St. George's Channel, or the German Ocean, none of them contain more than from 90 to 110 species; whereas from the restricted area of Sheppy alone, 83 fossil species have already been described; and if we add the undescribed species, the total number will probably exceed 100. Although these ancient fishes differ on the whole very widely from the like class of animals frequenting our seas at the present day, yet, notwithstanding this difference, there are indications at this ancient period of a tendency to a class distribution of fishes resembling in some points that which now prevails; but generally the distinction is great.

The two great divisions of fishes are, those without true bones, possessing only a cartilaginous or gristly skeleton, such as the Sturgeon and the Shark; and the ordinary fishes, possessing the common bony skeleton, such as the Perch and the Salmon. These again are distinguished by their teeth, their scales, and other structural peculiarities.

Both these classes are represented in the old sea of the London Clay; not, however, in the same proportion as they at present exist. The Shark and Ray tribes, now so rare on our coasts, seem to have swarmed in those waters. Few fossils are more common in the London Clay than the teeth of the Shark (fig. 32). They retain all their brilliancy and sharpness, and bear the closest resemblance to the teeth of existing sharks. The other parts of the skeleton, owing to their soft texture, are, with the exception of a few bones of the back, rarely or never met with.

Some of the old sharks must have been formidable creatures. A vertebra in Mr. Bowerbank's collection measures 4 inches in diameter. The fish to which this belonged was probably not less than from 30 to 40 feet in length. These voracious fishes, although occasionally now found on the British coasts, are essentially fishes of warmer seas. They are common in the

Mediterranean, and abound in the tropical and subtropical regions of the Atlantic. One of the varieties of the Shark is that known by the name of the *Saw-fish*. Even of this genus we find one species in the London Clay.

Land animals require teeth only to tear or bite their food, but fishes which live not only on sea-weeds or on smaller fishes, but also on shells and shell-fish, could not with ordinary teeth get at this latter food. Many such shell-eating fishes are therefore furnished with another sort of teeth, admirably and curiously adapted to meet the difficulty which would otherwise exist, of supplying themselves with food. Instead of having a single row of teeth fitting in the jaw alone, they have the whole of the upper and lower palates covered either with flat close-fitting plate-teeth (fig. 33), or else with some form of rounded teeth (fig. 34), between which they can crush with ease both shells and shell-fish. It was with crushing and grinding teeth of this class that a large proportion of the fishes of the London Clay period were provided. They form dark flat discs, about the size of the palm of the hand, lustrous and smooth on the grinding side, and finely lined but dull on the other, and consist of long plates (often found at Sheppy) closely set side by side like a piece of fine mosaic pavement (fig. 33). These curious fossils are the sets of teeth of a genus of the Ray tribe, now comparatively rare, as only 5 species are known to exist; whereas at the London Clay period it would appear that as many as 16 species existed in these latitudes alone. Not only did this peculiar section (*Myliobates*) of the Ray tribe abound at that period, but another curious family, the *Pycnodontes*, which has now not a single representative in existing creation, was also common at that time, as many as 10 species of it being found at Sheppy. These latter are so called from the bean-like form of their teeth. They were covered with a cuirass of large enamelled scales. A restored representation from Agassiz of one genus of these singular fishes, the *Pycnodus*, is given at the end of this Lecture.

There are, however, other fishes, with whose analogues we are better acquainted, of which the remains are found at Sheppy. Thus there are 2 genera very similar to the common Herring; another resembles the Eel; whilst there are 5 species closely allied to that serviceable class of fishes, the Cod and Whiting,

now so plentiful in the British seas. This is the more singular as these are essentially temperate and cold-sea fishes, whereas the greater proportion of the London Clay fishes have more affinities with those of hotter latitudes. One species resembles the Tunny fish of the Mediterranean; 3 genera are allied to the Teuthiæ, a family now living in southern seas only; there are 7 genera of the Sea-Perches—allied to forms now inhabiting the Mediterranean and the tropical parts of the Atlantic; and 4 species of the curious group of Sword-fishes. One species of Sword-fish is occasionally taken on our coasts, but these fossil species are more closely allied to a division of the recent family which never quits the southern seas.

None of the flat fishes, such as the Sole or the Turbot, have hitherto been found in the London Clay*.

Remains of Fishes of the London Clay period.

Fig. 32.



Fig. 33.

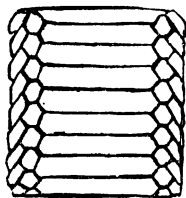


Fig. 34.

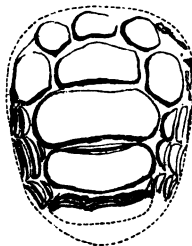


Fig. 36.



Fig. 35.



Otodus obliquus.
 ‡ Nat. size.

Myliobates striatus. *Phyllodus toliapicus?*
 (Drawn of natural size from specimens in the collection of Mr. Tennant.)

Vertebra of ordinary fish, 36; Shark, 35.
 Reduced size.

The Reptiles present a still greater departure from the distribution prevailing here at the present day. In England only fourteen species of Reptiles of all sorts now exist, whereas on the land and shore of the London Clay period we already know of 21 species belonging to a few genera only. In the present day a Turtle occasionally strays from its warm home in the Atlantic to our more northern coasts, but this is a rare circumstance. They are, strictly speaking, creatures of tropical seas. Hitherto all the tropical seas of the world have yielded

* See Agassiz's "Poissons Fossiles," and his interesting Report on the Fishes of the London Clay, published in the Transactions of the British Association for the Advancement of Science for 1844.

but 5 species of marine Turtles, and of these only 2 are known to frequent the same locality; and yet there existed here at the time of the London Clay, and within a very limited area, no less than 10 species of true marine Turtles of small size. Fig. 38 represents a fine carapace or dorsal shield of one peculiar Sheppy species; the head forms a separate specimen.

Another group of Turtles are those of which the shields, instead of being bony and hard, are cartilaginous and yielding. They are called "Soft Turtles," and frequent rivers. There are none found in Europe: one species inhabits the Nile, and another the rivers of Guiana, seeking for their food especially the eggs or newly hatched young of the crocodile. Prof. Owen has detected one species of this class in a fossil state at Sheppy.

The Marsh Tortoises form a third group. One species is found in all the South and in the North-east of Europe as far as Prussia, and another lives in North America. The remains of 7 of these creatures have been found in the London Clay. One species shows a striking approximation to a small African land Tortoise; another is a gigantic species, $1\frac{9}{12}$ foot long by $1\frac{5}{12}$ foot broad, far exceeding in size any known land Tortoise.

The next division of the Reptile order is that of Lizards or Saurians. The most prominent living family of this order are the Crocodiles, which, as you are well aware, now inhabit only the rivers of very hot countries. Prof. Owen observes that "at the present day the conditions of earth, air, water, and warmth, which are indispensable to the existence and propagation of these most gigantic of living Saurians, occur only in the tropical or warmer temperate latitudes of the globe." Two species of Crocodile have been met with in the London Clay. One bears some resemblance to the Nile species; the other species more resembles in some respects both the Gavial of the Ganges and the Crocodile of Borneo. Fig. 37 represents the fossil skull of the first from Sheppy*.

A single species of Serpent has been found at Sheppy. From the size of the vertebræ it must have belonged to a creature 12 feet in length; whilst, from their form, Prof. Owen considers

* Publications of the Palæontographical Society, for 1849: 'On the Che-
lonia of the London Clay,' by Profs. Owen and Bell, and 'On the Crocodilia
and Ophidia,' by Prof. Owen, from which works figs. 37 and 38 are formed.

that this Serpent more resembled the existing Boa than any other genus.

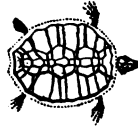
Reptiles of the London Clay period.

Fig. 37.

*Crocodilus tiliapicus.*

†† Nat. size.

Fig. 38.

*Chelone longiceps.*

†† Nat. size.

Birds.—Thus far, almost all the classes of existing nature have been largely represented at this old London Clay period; but as we now pass on to the higher orders of animal life, viz. to the birds and quadrupeds, we find indications of great comparative deficiency. Of birds we might expect to find but few in a marine deposit of this sort. A few, however, have been found, and they are interesting. According to Prof. Owen, one specimen may have belonged to a small species of Vulture; another (fig. 39) to a water bird having its nearest analogies with the Kingfisher; whilst other fragments, found in digging the railway at Primrose Hill, belong apparently to a small Wader. Mr. Bowerbank has also recently described some bones of a gigantic bird from Sheppey, which he considers to resemble the Emu.

Birds and Mammals of the London Clay period.*

Fig. 39.

*Halcyornis tiliapicus.*

‡ Nat. size.

Fig. 40.

*Hyracotherium leporinum.*

‡ Nat. size.

Mammals.—We only know of the existence of two quadrupeds at the period of the London Clay†. The *Coryphodon eocænus*,

* These figures are reduced from Owen (*op. cit.*), as are also figs. 8 to 12.

† Another quadruped, about the size of a fox, has recently been discovered in the London Clay of Harwich. Prof. Owen has described and named it, *Pholophus vulpiceps*.—Oct. 1857.

which belongs to that curious class of extinct thick-skinned animals more common in some of the Tertiary strata of Paris, has its nearest analogue in the existing Tapir of South America and Sumatra, but surpassed them by one-third in size. It is an extraordinary form, "supplying the transitional links connecting the Proboscidian* with the Tapiroid families of *Pachydermata*†."

The remains of another animal (fig. 40), belonging also, according to Prof. Owen, to the same thick-skinned class as the last, have been found at Herne Bay. It was a small creature, and probably, from the large size of the eye indicated by the capacity of the orbit, timid like the Hare, which it may have somewhat resembled in size, although its structure classes it in one of the families of the Hog tribe‡.

Plants.—In the Vegetable Kingdom, the London Clay furnishes us with a group as marvellous as those of fishes and reptiles in the animal kingdom. I have before mentioned the occurrence of the trunk of a fossil tree 40 feet long. But generally speaking the specimens of wood are in small pieces, which, from their being so frequently drilled by the old sea-worm, seem to have floated long at sea. The wood often exhibits its original structure almost as perfectly as specimens of recent wood. Little, however, can be made out of these fragments, except that they mostly belong to coniferous wood.

But it is the fossil fruits and seeds, found especially in the Sheppy Cliffs, which form so rich and interesting a flora. Only a portion of these have at present been described, but enough has been done by Mr. Bowerbank, by whom 114 species (out of several hundred) have been determined, to furnish us with their true affinities§.

Unfortunately, from the nature of the petrifying substance, iron pyrites, these specimens decompose by exposure to the atmosphere, and are with difficulty preserved. When first found, their shape and figure are very perfect, and even the form of the seeds, cells, and fibres in the substance of the fruits often

* Gr. *The trunk of an Elephant*,—a term applied to all animals with a similar appendage.

† Gr. *Thick-skin*. Animals with very thick skins, like the Elephant.

‡ Owen, 'British Fossil Mammals and Birds.' Van Voorst, 1846.

§ 'Fossil Fruits of the London Clay.' Van Voorst, London, 1840.

exists. The more delicate parts of the plant, such as the leaves, flowers, &c. are not met with; it is only the wood, seeds, and fruits which have escaped destruction; many classes of plants are, therefore, not represented in this fossil flora. The remains which are the most abundant, forming 45 species out of the 114, are those of the leguminous or pod-bearing order of plants, —a very wide-spread order, which includes not only our common beans, clover, &c., but also the liquorice and indigo plants, the Acacia, Tamarind, Gum Arabic, and many of the large and valuable timber trees of India.

Of the Cone-bearing or Pine order, which are chiefly ever-green, Sheppy furnishes 15 species—of forms most closely allied to the Cypress.

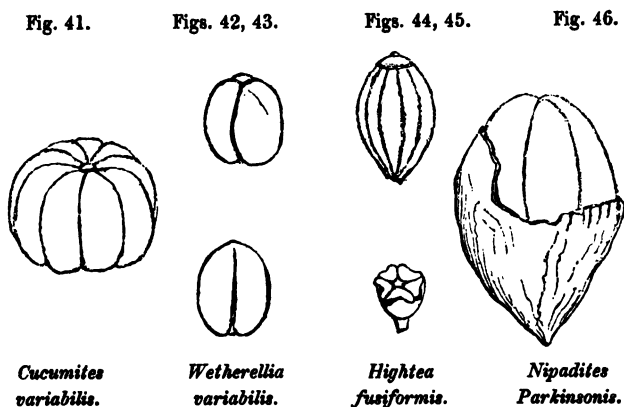
The most abundant, however, of all these fossils at Sheppy are certain fig-shaped fruits (fig. 46). They may be picked up in hundreds among the pebbles on the shore at the foot of the cliffs, from which they are being constantly washed out, together with the various other fossils, by the action of the sea*. These fossils bear a close resemblance to the fruit of the Nipa, a tree allied to the Palms, and now found fringing in great luxuriance the flat shores of many of the large rivers of India and of the Asiatic archipelago. We also find representatives (figs. 44, 45) of the Mallow order, which includes the Cotton plant; of the Orange or Citron (figs. 42, 43), and Melon (fig. 41) orders—miniature forms compared to their present cultivated analogues, but still elegant and delicate in shape in this their old wild state. Nor must I omit to mention that we find in the London Clay of Sheppy and Herne Bay some fossil fruit-cones belonging to a shrub closely allied to a group of plants now confined to the Southern Hemisphere, and more particularly characteristic of the vegetation of Australia.

All these fossil plants are now extinct, although their affinities can be established with considerable certainty. In the present day only 19 species of leguminous plants are indigenous in

* This, in fact, is the way in which almost all the Sheppy fossils are obtained. It is a very difficult task to procure them directly from the cliffs. Amongst the cottagers in Sheppy who collect these specimens for sale, the Nipadites (of which fig. 46 is an unusually fine specimen) are termed figs, and the segments of the Wetherellia (fig. 43), coffee-berries, which they really look like. Owing to their exposure, most of the specimens are a good deal defaced.

England; 3 cone-bearing trees; and 1 Cucurbitacea: the first-named order is one which is developed in excess in hot and tropical countries, and decreases as we approach the poles. The other Sheppy plants also resemble genera and families now existing chiefly and often exclusively in the warmer regions of the earth.

Plants of the London Clay period.



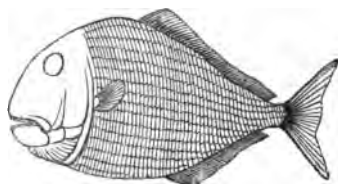
Figs. 44 and 45 are of natural size; 41, 42, 43, and 46 are reduced about one-half.

"The abundance and variety of these remains" indicate "the extent and nature of those dense primeval forests in which the great tapiroid animal, we have described as living at this old geological period, may have passed, like its existing congener the Tapir of America, a solitary existence, buried in the dark depths of these ancient forests, and satiating its ravenous appetite with the fruits, buds and shoots of those fruit-bearing trees with the fossilized remains of which it is now found associated*." Its only known companions were that timid hare-like pachyderm and the great boa-like serpent. Beyond these, those solitudes were probably but little broken, except by the harsh notes of a few solitary birds of prey or of some fishing birds. In contrast, however, with this desolation on the land, the waters swarmed with life. Large Crocodiles, accompanied by their constant egg-devouring enemy the fluviatile Turtle, sported in the rivers, and the seas teemed with a numerous population of Testacea

* Owen, *op. cit.* pp. 203, 204.

and Fishes. The remains of these things living on that land were borne down by the rivers, and became commingled with those living in the seas, but in a proportion and in a manner which constitute the latter the great and distinctive feature of the group, and clearly indicate the marine origin of the strata then and there accumulated.

Although we thus have evidence in the organic remains of the London Clay of a world of which the constitution was doubtlessly perfect of its kind, yet how differently constituted from the one now around us! How striking are these glimpses into the far past, and how wonderful the conditions then prevailing and the subsequent changes! For it was under this very sky that all these great tropical-like forests, and beasts, birds, reptiles, and fishes, of extinct forms, lived and flourished; while the wreck of all these extraordinary things of the past now lies buried beneath our feet, shrouded in that great mass of argillaceous strata, the London Clay—a tomb of countless generations of created things, whose life-beauty of form, colour, movement and structure we can, to a certain extent, picture to ourselves, although we can scarcely realise their former occupancy of the ground in presence of the bright and luxuriant covering of existing nature, which, while it fills the present and cloaks the past, does not, however, entirely preclude us from obtaining by diligence and care some insight into those singular scenes which preceded its own reign.



THIRD LECTURE.

EOCENE PERIOD (continued).

THE LOWER LONDON TERTIARIES, THEIR STRUCTURE, ORGANIC REMAINS, AND ORIGIN (*i*, Pl. II.).—CONCLUDING THEORETICAL CONSIDERATIONS.

ON the last occasion I gave you a short account of that great mass of argillaceous strata called the London Clay. I showed you that in it there were imbedded the remains of a large number of extinct forms of shells, crustaceans, fishes, and reptiles, of some few birds and quadrupeds, and of numerous plants and trees, almost all exhibiting characters similar or approaching to those which mark the analogous forms of life now peopling the warm and tropical regions of the globe; that the shells and fishes were such as now inhabit salt water, and consequently that this great mass of sediment must be of marine origin. This London Clay varies but little in character throughout a thickness of 400 feet, and although certain zones in it are marked by the preponderance of certain fossils, still it may be considered that the bulk of the same life and the same remains continued to prevail during all the period of its formation.

Far different, however, is it with the strata between the London Clay and the Chalk. In this series, which is here about 200 feet beneath the surface, the strata are very varied and irregular. They are termed the "Lower London Tertiaries," and are divided into three subgroups: the upper one, called the "Basement Bed of the London Clay" (*i*¹, Pl. II.), is a marine deposit, in mineral character resembling the beds beneath it, but in organic life more nearly related to the London Clay above it; the middle one, or the "Woolwich and Reading Series" (*i*²), is a very variable group of freshwater and æstuarine origin; whilst the

lower one, or the Thanet Sands (δ^3), is a marine bed of much less extent than the other two.

Basement Bed.—To continue in descending order, suppose you had traversed the 200 feet of solid London Clay, you would find at its base a bed composed of light-coloured sand full of flint pebbles, perfectly rolled and well rounded, like the pebbles on a sea-shore. Beneath us here, it is not more than from 2 to 3 feet thick*, but at Blackheath, where this old shingle bed comes to the surface, it is very much thicker; you may see sections of it from 10 to 20 feet thick in pits on the Heath, and at a few places on Plumstead Common it has been found to be from 50 to 70 feet thick. This great variation in its thickness arises from its filling up hollows and excavations in the beds beneath it.

This stratum alone constitutes the subdivision called the Basement Bed of the London Clay. Its organic remains are extremely varied both in their distribution and their character. It is in some places without fossils; in other places they abound. They are sometimes marine, and then they are mostly of the same sort as those we have already described in the London Clay; at other times they are æstuarine and freshwater, and they then contain many of the same species as those found in the underlying beds.

In the æstuarine portions of this deposit, which prevail near London, *Cyrena* (fig. 47), *Cerithium* (fig. 49), *Calyptræa*, *Cardium*, and *Pectunculus*, are common. At Stratford-le-Bow I found with these shells, in a conglomerate bed of this age, a thick fossil oyster-shell, perforated by one of those boring shells which exist mostly on or near a line of coast. Sharks' teeth are often very plentiful in this bed. It is not uncommon to find, at the pit at Woolwich, one species of *Cyrena* with both valves perfect, and in the vertical position in which it lived; and as bands of them are sometimes so placed, it is probable that they were from time to time entombed living, burrowing in the bed of those ancient seas, just as many existing shells burrow on present shores.

Some unique and remarkable fossils have been discovered in

* Not unfrequently this bed is concreted, as happens at Balham Hill and possibly here; it then forms a conglomerate rock, or puddingstone.

this bed at Kyson, near Ipswich. In the London Clay, at the base of which this bed occurs, we noticed the remains of only two land animals. Some years since Sir Charles Lyell remarked*, "We are led to infer, from the presence of Crocodiles and Turtles in the London Clay, and from the cocoa-nuts and spices found in the Isle of Sheppy, that at the period when our older tertiary strata were formed, the climate was hot enough for the quadrumanous (or monkey) tribe." The validity of the inference suggested by this distinguished geologist has since been established by the discovery at Kyson of some fossil teeth, which Professor Owen has determined to belong to a fossil Monkey allied to the *Macacus* of India and China, but of extinct species, and which, he observes, "constitutes the first example of any quadrumanous animal occurring in strata so old as the London Clay." "Cuvier, the great founder of that department of the science of organic remains which relates to the interpretation of the fossil bones and teeth of the vertebrated animals, had met with no evidence of any species more highly organized than a Bear or a Bat in the fossiliferous strata which formed the theatre of animal life anterior to the records of the Human Race. Not a bone, not a tooth of an Ape, Monkey, or Lemur had ever presented themselves to his notice during the long period of his researches, whence it came to be generally believed that the Quadrumana, or those mammals which most nearly resemble Man in their organization, were scarcely, if at all, anterior to the Human Species in the order of Creation." A few specimens have since been found, but still "the extreme rarity of the fossil remains of such highly organized animals in any part of the world, and the previous total absence of any in a land so far from the Equator,"† give unusual interest to this Kyson specimen. With the Monkey there have been found the remains of an *Opossum*, of an insectivorous Bat, of the *Hyraotherium*, and of a large extinct Serpent.

Woolwich and Reading Series.—Next beneath the above intermediate bed is the group which I have termed the "Woolwich and Reading Series," from the circumstance that the leading characters of the deposit are well seen at those two localities.

* Principles of Geology, 1st Edit. vol. i. p. 152.

† Owen, *op. cit.* pp. 1 to 10.

This is an intricate and curious series. At many places it consists of a bright red clay mottled with various other bright colours; at others these clays are mixed with beds of sand; elsewhere the series is composed of beds of pebbles, with layers of sands and carbonaceous clays, and further east, of siliceous sands only. In some places eastward it contains entirely marine fossils; nearer London, a mixed group of brackish and freshwater fossils prevail exclusively; whilst the mottled clays further westward contain no fossils at all*;—and all these are on the same horizon.

I will give you the succession of the strata in this series as they probably exist beneath us at this spot. As I have no sufficient details of any well on the Common, I will take the nearest deep wells of which I have the more exact particulars. There are two such sections, one at Balham Hill, and the other (a double well) in the Wandsworth Road, about two miles from Vauxhall; the section given in Pl. II. is a mean taken from these two localities. At the first place the London Clay is found to be 240 feet thick; in the latter 134 feet. The following detailed account of this well shows a section of the Woolwich and Reading series, differing probably but little from that which exists here.

Mean of two adjoining Well-sections in the Wandsworth Road.

	Feet.	In.	
1. Brick-earth and gravel	13	0	<i>Drift.</i>
2. Blue clay	134	0	<i>London Clay.</i>
3. Sand and flint-pebbles	1	8	} <i>Basement Bed of the London Clay.</i>
4. Shell-rock and pebbles (commonly called the Oyster-shell Rock)	2	2	
5. Black clay	1	8	} <i>Woolwich and Reading Series.</i>
6. Brown clay	2	7	
7. Mottled red and blue clay	15	8	
8. Greenish sand.....	1	0	
9. Grey and white sand	4	0	
10. Black and yellow clay, <i>with shells</i>	1	0	
11. An argillaceous limestone	1	8	
12. Mottled red, yellow and blue clays	19	0	
13. Black sand	1	6	
14. Greenish sands and flint-pebbles	7	9	
15. Light ash-coloured sands	32	0	<i>Thanet Sands.</i>

At this point the well ended, but we know by other wells not far

* The *Ostrea Bellovacina* often forms beds at the base of these Clays in Berkshire, but I never found them in the body of the clay.

distant, that the last sands (No. 15) are about 40 feet thick, and that they lie upon the chalk.

Eastward of London this series changes rapidly. Thus at the great ballast-pit immediately on the Greenwich side of Woolwich and adjoining the road, you will find no mottled clays, but in place thereof a succession of strata full of freshwater and æstuarine shells; the same is the case at Upnor, near Rochester; whilst if you examine the synchronous* beds near Canterbury and Sandwich, you will meet with nothing but siliceous sands, which, in the neighbourhood of Richborough and Ash, contain some beautiful silicified marine shells and fossil wood.

Westward of London the mottled clays predominate; they are well exhibited next to the chalk at Alum Bay in the Isle of Wight, and extend even over a large portion of the French Tertiary area. Hand-specimens from Meudon, near Paris, could not be distinguished from Reading or Ewell specimens. It is a remarkable case of a zone marked by mere mineral character; and its persistence is the more noticeable, inasmuch as the more important mass of the London Clay itself has not so wide a range. The exact relation of all the strata composing this series was long doubtful. It was within an area of about six miles round this very district, that the key to their true order was discovered. It then appeared that, different as the sections were at different places, yet that the mottled clays, the fossiliferous clays and sands, and the pebbly sands, are not superimposed in one given order, but that they are intercalated and dove-tailed one into the other; and that consequently they are synchronous, being merely the result of the different conditions under which the deposit was forming at the same time in different parts of the same waters.

The organic remains of these beds are of a very distinctive character. I will first take those of the London district, including Woolwich, Bromley and New Cross, where they are most plentiful. It is a peculiar feature of a freshwater fauna, that although fossils may abound—may form whole beds,—yet that they consist of very few sorts: the individuals are in thousands, but the species are very few. Thus, at Woolwich

* Corresponding with; of the same age.

you can procure in the course of ten minutes handfuls of fossil shells, more or less perfect, but on examination you will find that the bulk of them consists of some four or five species. The characteristic shell of this group is an extinct species of oyster, much resembling our common edible oyster. At Bromley it is also found in great abundance, several specimens being often attached to a single large pebble, which shows the state of tranquillity of the spot at that geological time. At Lewisham and under-ground in this district this fossil is also common.

In the greenish sand and shingle (No. 14), at the base of this series, we often find the same *Ostrea Bellovacina* in patches, in such abundance as to form real oyster-beds. At the artesian well at the Bank of England, there is a seam of them 4 feet thick, at a depth of 192 feet beneath the surface. At Reading*, where these lower strata rise to the surface, there is a well-known bed of this shell immediately on the chalk. There is another, 4 or 5 feet thick, in the same position, on a hill one mile E.N.E. of Newbury. These oysters evidently lived and died on the spot where they are now found. The shells are often double and perfect, and in the position in which they lived. They also constantly show the destructive effects of the minute boring sponges with which the recent shells are so commonly drilled. This is a small matter, but it adds nevertheless to the strength of the links between the past and the present, in showing the resemblance of the life-conditions of these distant periods, alike even in these minute and comparatively insignificant arrangements. Here are certain Testacea congregating in shoals as they now do, locating in sheltered spots, feeding probably upon abounding marine infusoria, and forming in their turn the fit habitation of those small creatures,—the next in order of organisation and almost the next in size,—the parasitic sponges, which found in their shells a suitable and protected dwelling-place.

Another common bivalve shell is the *Cyrena* (fig. 47), one species of which lived in England up to a very recent geological period (occurring in profusion at Grays, associated with the remains of the large Mammals, in beds of sand and gravel belonging to part of the Drift period last described). This genus is, however,

* The Katesgrove Pits. The Thanet Sands are wanting in Berkshire.

no longer found living in this country, but abounds in some of the rivers and mangrove swamps on the coasts of Tropical America, Egypt, India, and Australia.

A third is the *Cerithium* (fig. 49), a univalve shell abounding in rivers, in salt lagoons, and on some sea-coasts: a great number are found in the mud of the Indus. A peculiarity of some species of this mollusk is, that they can live for a long time out of water, for they are often found crawling on the land and on trees at some distance from the rivers they inhabit. The freshwater forms of this shell are confined to the tropical regions of the Old World, but the marine forms, which can hardly, apart from their association, be distinguished from them, have a world-wide range, although even of these latter the typical species are tropical. Still there are some species of this genus now existing in the seas of Norway and Britain.

The *Melania*, a univalve found in the fresh waters of temperate and hot climates, is another very common Woolwich shell. Another rather less common shell is the *Melanopsis* (fig. 50), a univalve likewise inhabiting fresh waters. This genus, extinct here, still lives in Spain, Asia Minor, and New Zealand.

There are some rarer species (common however at New Cross), which yet more particularly indicate fresh water; these are the *Unio* or freshwater mussel, and the *Paludina* or river-snail, both genera abounding in our present rivers and ponds.

Shells of the period of the Woolwich and Reading Series.

Fig. 47.



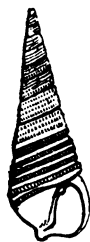
Cyrena
cuneiformis.

Fig. 48.



Modiola
Mitchelli.

Fig. 49.



Cerithium
variabile.

Fig. 50.



Melanopsis
buccinoides.

Other of the shells of Woolwich and New Cross are distinctly marine or æstuarine, such as the *Corbula*, *Nucula*, *Arca*, and *Modiola* (fig. 48). The marine shells do not on the whole indi-

cate so warm a climate as the freshwater shells. The cause of this I will allude to presently. The total number of all the shells found in this series amounts only to 44 species.

The small *Entomostraca** are very numerous. They are about the size of the grains of cress-seed, and require considerable care and search to distinguish them from the grains of the sand with which they are mixed.

There are also rare traces of Turtles and of Crabs; whilst, judging from the number and variety of teeth, two species of Shark seem to have been common. A few other fish-bones and some fish-scales are found, and amongst the latter those of a remarkable large enamelled-scale fish, called the *Lepidosteus*, a genus of Ganoid† fishes, now peculiar to the lakes and rivers of North America. The only remains of mammals met with up to the present time is the tooth of a *Lophiodon*, said to have been found in these beds in digging a well at Camberwell. One small bone of the foot of a bird has been discovered at Deptford, but it is a bone not of sufficient character to enable Prof. Owen to determine even the genus of the bird to which it belonged.

Traces of vegetable remains are common. In this district they merely form seams of black carbonaceous clay, which at places, as at Mitcham, passes into a bed of lignite (a soft and imperfect woody coal), 3 feet thick. Generally, however, the seam of lignite does not exceed 6 to 12 inches in thickness. I remember some years since seeing a considerable quantity of this lignite dug out of one of the clay and sand pits at Lewisham. It was thrown in a heap on one side. The decomposition of the iron pyrites, small portions of which it contained, caused it to ignite spontaneously, and it continued smouldering for several months. This irregular seam of lignite is found in places under the thick bed of shingle, before alluded to, which covers Blackheath. It is the circumstance of meeting with it occasionally in digging wells in that district which has so frequently given rise to the report of coal existing there. But this lignite, besides being in insignificant quantities, is, owing to the impurities with which it is mixed,

* Gr. *Insect-shell*; minute crustaceans with a shell or carapace opening in two pieces like a bivalve shell. They are found also in the London Clay.

† Gr. *Polish*. A family of fishes with bright enamelled scales.

quite useless as a combustible. The microscope shows the structure of these lignites to be chiefly that of coniferous, or cone-bearing, trees, although other dicotyledonous woods, *i.e.*, wood of those trees which grow by the addition of successive layers on the outside of the old wood immediately under the bark, and which have leaves with veins like network,—a class comprehending three-fourths of all the known plants in the world,—are met with. Nor are there wanting the remains of monocotyledonous woods, *i.e.*, of those which, as in all the Palm tribe, grow by the addition of fibrous matter within the stems, that increase but little in size, and show no medullary rays, or none of those rings so conspicuous in ordinary wood. The leaves of a species of Fern, resembling an existing genus, is found in some abundance in one thin stratum at Counter Hill near Lewisham. With these there have also been found a few rare and curious little fossil seed-vessels, about the size of a currant; they are so perfect, that all their structure can be perfectly well made out, but they cannot be referred to any known genus of plants.

Although the vegetable remains are thus few and imperfect in the vicinity of London, elsewhere in this series their characters are better preserved. For example, in the Woolwich Sands at Ash, near Sandwich, there are found pieces of wood converted into stone as hard as, and of the structure of, flint, and yet showing under the microscope their vegetable structure almost as perfectly as in a recent plant. They belong to both the great classes of trees just mentioned. A few years since I also found in one of the beds of sand at Herne Bay a fossil cone of a Fir-tree, belonging apparently to an existing genus (*Abies*).

The most remarkable group of plants, however, of this series, and one of the most perfect and beautiful in any fossil flora, was that which I met with a few years since in the railway cutting just west of Reading. The fossils were in a thin bed of laminated clay, at the base of the mottled clay and a few feet above the chalk. On splitting this clay, hundreds of leaves, impressed as finely as on wax, and with every marking preserved, were exposed (see figs. 51, 52, 53). So perfect is the state of preservation of these leaves, that you would suppose that their relations with existing species could be easily and exactly determined. But this is not the case. A seed-vessel, a flower, or a fruit, are of

more importance than a leaf in determining the analogies of plants. Dr. Hooker, the eminent botanist and traveller, to whom I am indebted for an interesting report on these fossils, has not deemed it safe to speculate with any certainty on their relations*. I will put before you some of his conclusions in his own words; his observations will at the same time serve to show you the great caution required not to judge too much by mere resemblance of form. He says, in regard to the genera to which these impressions might be referred, "None of them afford sufficient data for approximating to the generic affinities of the plants to which they belonged. After a careful collation of the specimens with many existing plants comprised in the present floras of Europe, Northern Asia, and North America, I find no characters by which they may be allied to those of one of these countries more than another. Indeed I feel satisfied that similar forms of existing plants might be associated by natural causes in any of these countries, but that they would not necessarily belong to the same species or even genera, in all. I do not see that any objection can be urged to the assumption that the climate of the epoch during which these plants flourished was a temperate one, experiencing summer heat and winter cold, and that it was not colder than that which now prevails in England; for the large size and membranous appearance of many of the leaves, which, like those of the maple, lime, poplar, &c., are annual, indicate some duration of summer warmth, and the leaf-buds are similar to those of various trees which lie dormant for a considerable period of the year. Still I have no hesitation in saying, that were I assured from collateral evidence of the flora of the Reading beds being intimately allied to that of India, I should find no difficulty in producing the allied living representatives; and the same may be said of the vegetation of many other parts of the globe; it requires, however, some general acquaintance with the plants inhabiting different parts of the world, to appreciate the fallacious nature of the evidence afforded by leaves; these being of all organs the least important for the higher purposes of classification." We have particularly to observe on the fact of "the total absence of any remains indi-

* *Quart. Journ. Geol. Soc.* vol. x. p. 163.

cative of a tropical vegetation ;” for otherwise “some more direct evidence of their origin would have been forthcoming.” In reference to the species, Dr. Hooker remarks, that “though the leaves preserved in the Reading beds are all of the very commonest forms in the vegetable kingdom (of Dicotyledonous plants), I do not find that they exactly resemble those of any living English species.”

Plants of the period of the Woolwich and Reading Series.

Fig. 51.



Nat. size.

Fig. 52.



Nat. size.

Fig. 53.

 $\frac{1}{4}$ nat. size.

Dr. De la Harpe, of Lausanne, who has paid great attention to the Tertiary floras of the Continent, and has also carefully examined my collection within the last few days, is, however, disposed to hazard more definite conclusions. He considers that the most common Reading leaf (fig. 52) may be referred to the fig or mulberry order. Other specimens he assimilates, with more or less doubt, to the walnut, laurel (fig. 53) to the spice-bearing *Eugenia*, to the soapberry tree, to the rhus or sumach (fig. 51), and the cassia; all these are natives of warm temperate, or of subtropical countries. Many of them will flourish in England, but the only indigenous tree of which Dr. De la Harpe found traces, was the oak. On the whole he thinks that this flora indicates a warm rather than a tropical climate—one in which we might have a luxuriant summer vegetation, with a fall of the leaf in winter, rather than the constant verdure and evergreen and tropical vegetation of which we have had evidence in the succeeding period of the London Clay. His opinion with respect to the absence in this group of plants of distinctly tropical forms coincides with that of Dr. Hooker.

These conclusions as to the noticeable fact that the climate of

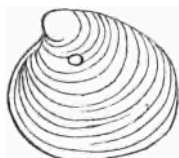
that period was not so hot as that of the succeeding London Clay, agree not only so far between themselves, but they also corroborate the evidence drawn from the other organic remains.

The dark bed of pebbly sand forming the base of the Woolwich and Reading Series reposes upon an uneven surface of light-coloured Thanet sands, into which it seems worn, or rather the pebbles and dark green sand of the one often seem splashed into the soft whitish sand of the other, as though they had been spread rapidly and somewhat violently over it.

Thanet Sands.—These fine quartzose sands (p³ Pl. II.) are so termed from their being best developed in and near the Isle of Thanet, as at Pegwell Bay to the west of Ramsgate, Richborough near Sandwich, and in the Reculver Cliff near Herne Bay. They vary in thickness from 40 to 80 feet. In this district, where they are from 200 to 300 feet beneath the surface, and also at their outcrop east of London, few, if any, organic remains have been found in them; but at the places just mentioned they are often rich in fossils, all of marine forms. The number, however, of species of Testacea amounts only to 40, of which 10 are univalves, and 30 bivalves. There are also 8 species of Foraminifera, a few scales and small bones of fish, traces of crustaceans, fragments of plants, and siliceous spiculæ of sponges. The characteristic shell of this series is the *Cyprina* (fig. 54); an *Astarte*

Shells of the Thanet Sands Period.

Fig. 54.



Cyprina
Morrisii.

Fig. 55.



Astarte
tenera.

Fig. 56.



Panopæa
granulata.

Fig. 57.



Sclaria
Bowerbankii.

These figures are about half the size of the specimens.

(fig. 55), the *Panopæu* (fig. 56), a *Cucullæa*, a *Nucula*, and a *Cytherea*, are also common. Here, again, it is remarkable that the greater number of the shells of this formation do not indicate seas differing so much as to warmth from those of our own coast as do those of the London Clay. Many of them

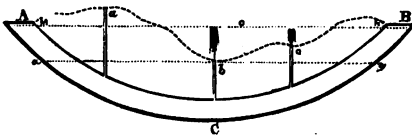
seem the snells of cool temperate or even northern seas. Still there are several southern genera.

A point of interest connected with these Thanet Sands, is that they form, underneath London and adjacent districts, a large and important water-bearing stratum—that which supplies all the early and many of the later artesian wells*. The way in which such wells act is this:—The Thanet Sands in the above-named area are separated from the surface by a mass of London Clay of variable thickness. As this clay is impervious, none of the rain-water which falls on its surface or the gravel above can pass downwards, nor can any water in the beds beneath rise upwards through it. But the Thanet Sands themselves being very permeable, wherever they rise to the top of the ground, as at Croydon and Epsom to the south of London, or at Stortford and Broxbourne to the north, they form a surface into which the rain which falls on them, together with that which drains from off the adjacent clay-lands, can penetrate easily. Now as these sands dip beneath the London Clay, and pass underground all the way from the above-named places to London, the rain-water, which sinks into them at their outcrop at these places percolates without interruption throughout all their subterranean course. And as the Chalk beneath and the Clays above the sands confine the water like two impervious plates, the successive additions of rain-water at the outcrop of the sands will, in process of time, gradually fill up the underground portion of this water-bearing stratum. Then any further addition of rain-water would only cause an overflow, as springs, at the edge of the sand-bed wherever there were depressions in it. This being the normal state of things, if an artificial opening were made through the London Clay down to the Sand-beds, the water in them would naturally tend to rise through any such opening to that level at which it stands at the outcrop of these Sands, which, at the above-named places, varies from about 60 to 100 feet above the Thames; that rise being however interfered with more or less by resistance dependent on the texture of the sand, &c. It was found, when artesian wells, as such artificial openings or borings are called, were first made in London, through the

* A large proportion of these wells are now carried down to the chalk, a better supply of water being obtained from fissures in that formation.

impervious clay down to the permeable sands, that the water from the Thanet Sands rose to a height of 20 to 30 feet above the level of the Thames. Now, however, these wells are so numerous, that the drain on the water-bearing strata in the London area is in excess of the rate at which they are replenished, and consequently the water-level, instead of rising above ground as formerly, now stands at from 40 to 50 feet below the surface. Still, at a short distance from London many of these wells continue to act nearly as at first. There are several good instances of them in this neighbourhood. One of the best is at the copper-mills at Garrett. The water there rises from a depth of 143 feet, and overflows in a constant and steady stream capable of attaining a height of about 20 feet above the ground. There are also overflowing artesian wells at Wandsworth, Tooting, and Mitcham; as likewise at Clapton, Tottenham, and Waltham Abbey on the north of London*. The

* Let A C B be a glass tube filled with water to m and n . If, then, three small tubes, a , b , c , be inserted in the larger tube, A C B, the water will tend to rise through them to the level of the line $m o n$. In tube a the water will rise to the level, $m o n$, and there stand. But as the tubes, b , c , do not reach the level of the line $m o n$, the water will jet through those openings, and not cease flowing from b , until it is lowered in A C B to the level $x y$. If, however, the water in A C B be kept constantly replenished, then the fountains from b and c will continue to flow permanently to heights varying as the distances from b and c to the line $m o n$. This is precisely what takes place in nature. A C B may represent a section of any bed of sand through which water can pass; and the sides of A C B, the impermeable beds of clay or stone which overlie and underlie the sands. $m n$ mark the levels of the outcrops of the sands at A and B, and so long as the rain falling on those outcrops replenishes the quantity



escaping at the artesian borings, b and c (supposing the line m , a , b , c , n to be the surface of the country, and the difference of level between a and b to be 45 feet), so long will the water overflow at b , say 30 feet, at c 15 feet, while at a it will form a permanent underground spring 15 feet beneath the surface. If, however, more water escapes at b and c than is supplied by the rain-fall, or more rapidly than fresh supplies can travel through the sands, then the level of the springs will gradually fall from $m o n$ to $x y$, when the water will cease to flow from the last of the wells b ; but may still be obtained by sinking shafts below the surface to reach the level of $x y$. This is, in a few words, the general principle on which the artesian wells around and

water of these deep-spring wells is very limpid and soft, but it nevertheless holds in solution a large proportion of solid ingredients, not less than 40 to 60 grains to the gallon, whereas our harder river-waters usually contain from 16 to 24 grains only.

At the base of the Thanet Sands you will generally find a layer, 1 to 2 feet thick, of large chalk-flints, but little worn, and imbedded in clay and greenish sand. These flints present the peculiarity of being stained outside of a deep olive or bottle-green colour, which gives them a character that cannot be mistaken when once seen, and which always serves to indicate their origin, for in no other of our Tertiary strata are flints of that colour found. This bed of flints forms the base of the London Tertiary series; next under it is the great body of Chalk, which, extending on the south of London from Woolwich, by Croydon, to Guildford, and on the north by Bishops Stortford, Hertford, St. Albans, and Watford, forms, between those two lines, a trough, in places 400 to 500 feet deep, filled with the Tertiary deposits we have just described. Altogether, these latter constitute a mass of strata about 150 miles in length from east to west, with a breadth varying from two to fifty miles, and a maximum thickness, exclusive of the Bagshot Sands, of about 600 feet.

The Chalk is far older than the Tertiary strata; it belongs altogether to a different period and different conditions. There is as little in common between the two as there is between the first Tertiary formations and the present time. Into this older chapter of the earth's history I do not enter, my object having been to give you some account of the Formations above the Chalk, with which I am best acquainted. I may however mention that the chalk beneath us is probably about 550 feet thick; that still lower, is the formation called the Upper Greensand (the fire-stone of Godstone), 50 feet thick; the Gault, or blue clay, on which the village of Merstham stands, 140 feet thick; and then, if in place here*, the Lower Greensand of Reigate and in London act. For fuller details see my 'Geological Inquiry respecting the Water-bearing Strata of the country around London.' Van Voorst, 1851.

* I must, however, observe that at Kentish Town, which is the only place where the chalk has been traversed in the London district, there were found a series of red clays and hard sandstones in the place of the loose light-coloured sands of the Lower Greensand.

Farnham,—a series of sands and sandstones from 500 to 600 feet thick (See Sect. 1, Pl. I.).

Theoretical Considerations.—Having thus briefly described the Tertiary strata in descending order, I will now enter into a few speculative inquiries suggested by the observed facts; and by taking the strata in the reverse order, *i. e.*, in the order of their formation, we shall pass through, and can depict, some of the many changes which this portion of the earth's surface has undergone from the period when the Eocene Strata began to be deposited on the chalk, to that later geological period, when the gravel was spread over and completed the surface of the London Tertiary area. This is a theoretical question, but we are in possession of a sufficient number of known and exact facts regarding the structure of the strata and their organic remains, to warrant us in drawing some few general conclusions with regard to the appearance of this part of the world at the different geological epochs described, and in so doing we are not exceeding the bounds of fair and legitimate deduction.

In this essay you must blot out from view the existing distribution of land and water—the present physical geography of Europe—and consider the land solely with reference to what we know was dry land, or better still, to what we know of the extent of the ancient seas, at the various geological periods.

As our survey commences before the deposition of any newer or Tertiary strata on the chalk, we must bear in mind that the whole surface of that chalk was at that time, necessarily, bare and uncovered*. It is known that the chalk extends S.S.W. from Yorkshire to Dorsetshire, and that it also extends underground, beneath the Tertiary strata, over the whole of the south-east of England †,—the London Tertiary area being a portion of the ground so covered. Again, Paris and Brussels stand, like London, on Tertiary strata, which did not exist at the time we are speaking of. Following the chalk in this way, removing the Tertiary strata and filling up the rents since produced, we

* The chalk itself is a marine deposit abounding in organic remains, a great portion of which are such as would have lived in deep waters,—the waters probably of a great and warm ocean.

† Except where the chalk is broken through and denuded by subsequent operations, as between the North and South Downs, which probably were once continuous; also between the coasts of England and France.

shall find that, at that old period of time, a continuous mass extended from the eastern and southern coasts of England to Denmark, Holland, Belgium, and the north of France, passing thence in one direction into Central Europe and in the other into Spain and Italy. Here and there through this chalk tract rose a few old mountain-chains and a few old lands, but none of the greater mountain-chains of Europe then existed. It was after the deposition of the Chalk that the mountain-chain of the Pyrenees was formed, a disturbance possibly accompanied by an extended and general elevation of the yet uncovered Chalk, raising and converting its sea-formed strata into a great and new continental area. That this freshly formed Chalk surface here constituted a dry land for a very long period of time is probable from the circumstance that when it was again partially submerged, the newer sea-formed beds, which are spread over it—the lower Tertiary strata—encased the remains of an organic life so entirely different, that, with one doubtful exception, not a single species of the races of animal life peopling the seas at the chalk period was any longer in existence. The whole face of nature had changed. New plants, new animals, new reptiles, and other tribes, had appeared, and all the former species had become extinct. Still a certain relation in several generic forms, and a certain resemblance in some specific characters, are apparent between the two periods. Nor must we fail to remember that a certain amount of difference would necessarily exist, even supposing the formations to have been closely consecutive, because the older one was deposited in a large and deep sea, and the newer in smaller seas, æstuaries, and lagoons, conditions which would of course occasion a difference of the animal life inhabiting such different waters.

The first Formation we find overlying the chalk is the Thanet Sands ; they extend but a short distance west of London, and are not found south, in the Isle of Wight or in the vicinity of Paris, whereas they have a continuous eastward range through Kent and Essex into Belgium. We therefore infer that, although the chalk must at that period necessarily have again become submerged to the extent indicated by the presence of this deposit, yet that all that portion of the chalk, or at all events the greater portion of it, to the southward of the

area so covered, yet remained in the state of dry land. And as we can follow the Thanet Sands northward and north-east in the Tertiary area, and we find in them several genera of shells such as chiefly frequent northern seas, with few of the numerous tropical genera which we meet with at a later period in the London Clay and more particularly in the Bracklesham Sands, we further infer that this oldest Tertiary sea had a northern extension. It was, probably, on the shores of the dry land of this period, that the innumerable flint pebbles so perfectly rounded,—a process indicating a vast lapse of time,—which we find in higher portions of the Lower-Tertiary strata, as at Blackheath and Addington, were formed; these accumulations of shore-pebbles having been spread out over the Thanet Sands at that next succeeding Lower-Tertiary period.

After the period of the Thanet Sands a further subsidence took place of the northern part of the southern continental area before mentioned, and the sea then spread itself over the greater part of the Isle of Wight and Paris Tertiary districts, leaving some of the higher lands as islands. One of these islands occupied probably the area now forming the Weald of Kent and Surrey,—then not denuded of all its chalk dome. It was during this second period that the strata of the Woolwich and Reading Series were formed. I have pointed out to you that in its eastern area this series is formed of sands containing marine shells exclusively; whilst further southward and westward it consists of alternating beds of freshwater and æstuarine origin, *i. e.* of beds formed at the mouth of a river, or in lagoons sometimes fresh and sometimes salt; for several of the shells, as the freshwater mussel and a few others, are such as could only have lived in fresh water, whilst some others are of genera such as might now be found in the æstuary of the Thames, the Rhone, or the Nile, or any other large river. This fact, added to the circumstance of finding much drifted wood and impressions of such delicate parts of plants as the leaves, which could not have withstood any long transport or exposure without undergoing decomposition, shows that land was doubtlessly very near to the spot where such remains were entombed. Land and river debris of this description are scattered through the Woolwich and Reading Series, sparingly at Guildford, rather more abun-

dantly beneath this spot and London, and in singular profusion at Woolwich and at Upnor near Rochester. These æstuarine deposits must mark a line of old coast. In a small pit, now filled up, at a short distance N.W. from Charlton Church, I once found a thin seam of iron sandstone, the surface of which was covered by distinct ripple-marks, such as may be now seen on any sandy shore at low tide. Further, as all these fluvial and æstuarine deposits are comparatively small both in extent and thickness, we infer that the rivers which formed them were also small, and consequently that they flowed through and drained a land probably of but limited area. Now, at Newhaven near Brighton, on the other side of the chalk downs, we have a tertiary deposit of similar character and formed apparently by another small river. This might mark the south side of the island, the northern shore of which is traced, as just mentioned, by the small river-deposits of Upnor, Woolwich, London, and Guildford. Similar local islands and similar river-deposits, though varying in local details and many of them larger, characterize the same series in France. Also, common to both the Paris and English areas, and of far wider range and importance, are the great beds of unfossiliferous Mottled Clays we have described as ranging from London to the Isle of Wight and Paris. The origin of these clays is perfectly independent of, though coeval with, the fluvial and æstuarine beds of the same Woolwich and Reading Series; they are the scouring of a much greater land and of greater rivers,—probably of the great southern continent we have before mentioned, which may have stretched from Ireland and Wales across to Cornwall, Brittany, and Spain. What now remains of that old land shows the preponderance in many places of igneous and granitic rocks, and there is reason to suppose that it is from the decomposition of such rocks that the peculiar mottled clay of this series was derived. The sketch at the end of this Lecture may serve to give some rough idea of the relation which the geography of this epoch of the past bears to that of the present.

If our surmise be correct, that, southward of the Paris and English Tertiary districts, extended a large area of dry land, whilst, on the coast and in the seas on its northern shores, the Lower Tertiary strata were deposited, we shall have a reason why the

marine shells of that period exhibit a far more northern facies than do those of the subsequent eocene periods; for those Lower Tertiary seas, being open to the north, might have had their temperature lowered by an inset of cold currents from more northern seas. The same cause may have affected the climate of the coast, and of the islands off that coast, to an extent which led to the existence of a flora of a far less tropical character than we might have expected, looking at that of the succeeding London Clay period; for we have seen that the vegetation of the Woolwich and Reading Series is such possibly as might exist in a comparatively temperate climate. The trees of that period, although showing perhaps a rather high summer temperature, yet indicate a certain winter cold. The flora, however, alone would not suffice to determine the temperature of the period; but taking it in conjunction with the other organic remains, we may, I think, infer that the climate was, on the whole, that of a temperate region,—yet considerably warmer than any in these latitudes now; for, although the marine shells are mostly such as might live on our present coasts, many of the freshwater shells belong to genera which certainly now frequent the rivers only of warmer regions than our own, while the presence of turtles, sharks,—and of crocodiles in the French series,—tends to support the same view.

And now was the old island between the north and south downs gradually and perhaps totally submerged, for the London Clay, which next succeeds, shows the encroachment of its marine strata over the former freshwater strata. The sea yet remained open to the north, and still there was land to the south, and on that land we have seen that there flourished, during this London Clay period, a marvellous assemblage of noble forest trees, of various fruit trees, of elegant and graceful palms, of wiry-leaved evergreens, and of gigantic succulent climbing plants—the food of a few pachydermatous and marsupial quadrupeds, and possibly of troops of a peculiar Indian monkey. These animals, together with a species of large boa-like serpent, alone, as far as we at present know, tenanted these dense and luxuriant primeval forests. The swamps and low tracts swarmed with marsh tortoises; the ponderous and voracious crocodile tenanted the rivers; whilst on the coast the

sea teemed with a wonderful population of curious fishes,—some covered with large enamelled scales, others possibly such as now grace the tropics with their bright and brilliant colours, sharks of gigantic size, and singular palate-toothed ray-tribes,—with corals and crustaceans less antique-looking, and with shells of varied and beautiful forms, amongst which the elegant *Nautilus* held a conspicuous place. Differing widely from the life of our own world, preserved only in part and disfigured by their burial, yet are we able, with the assistance of those eminent naturalists conversant with every form of living things, to reconstruct these remnants of a past period into a fragment perhaps, but a magnificent fragment of an old world—a world showing, like the present one, life in various forms, with a vegetation on the land and in the waters fitted for the support of various herb-feeding creatures, with microscopic things in the seas as food for numerous mollusks, and mollusks as food for many fishes,—all again subject to become the prey of the numerous larger predatory creatures which form the due and ever-accompanying complement to such a population.

During all the period of the London Clay there is evidence that the bed of the sea was being gradually depressed; so also, to a certain extent, the southern continent we have pictured to ourselves. For the next overlying formation, the Bagshot Sands, has a far more southern range, extending to beyond Paris,* and occurring again in the south of France. Many new creatures succeeded several of those of the preceding period, and the seas of these latitudes being opened out to other seas in the south, a host of shells of hotter-sea character made their appearance.

In speaking of the temperature of the seas at these old geological periods, I am willing to allow that the climatal changes to which I have alluded, resulted, to a great extent, from changes in the distribution of land and water on the surface of the globe; and in this respect it is interesting to trace at these far-distant periods, when all was different but the mass of our planet beneath and the skies above, the operation of those same climatal laws which prevail at the present time. But, although fully admitting this, and the importance of explaining in every case, when possible, past changes by causes still operating, yet there are cases

* The Lits coquilliers, Calcaire grossier, and Sables moyens of the French.

which so far deviate from any conditions that could now obtain, that we are obliged to seek for other causes in explanation thereof. Thus we can explain by causes such as might now come into operation,—by changes in the distribution of land and water,—why the temperature of the first Tertiary seas was cooler than that of the seas of later Tertiary periods. But the effects resulting from such changes have their limits, and these are far exceeded when we take cognizance of the temperature which seems to have prevailed during the London Clay period; for then, as I have shown you, reptiles of hot climates, and shells and fishes of tropical seas, swarmed in this latitude, whilst the land was clothed with a varied tropical-like vegetation. Surely no possible modification in the distribution of land and sea could now produce so great a change,—could here give rise to a heat so high and so maintained. If England were now so situated as to possess a temperature lower than other places in the same latitude, then we might suppose a time when, under different hydrographical conditions, the climate was warmer than at present. But so far from this being the case, England is, as before mentioned, placed under conditions for warmth quite exceptional: its temperature is now an extreme of moderate for a country in a latitude thus far north. The mean normal winter temperature due to such a position, is many degrees lower than that which we enjoy. Instead of a Siberian cold, our January temperature is but little lower than that of the south-west of France and Northern Italy; but, on the other hand, there are places in the same latitude as we are here, which have a short summer temperature equal to that of Portugal. The great winter-cold due to our geographical situation is wonderfully tempered by our insular position in the course of the Gulf-stream, while the same location lessens also the summer-heat. Still even no greater amount of summer-heat, such as might be possessed by any place in the latitude of London, combined with a winter temperature so abnormally high as our own (supposing such a thing possible), could have sufficed for the existence of a fauna and flora like that which flourished at the period of the London Clay. The extra heat of that period must, therefore, have been due to some other cause; what that was we cannot now stop to inquire. What I wish to point out to you is, that there was some cause then in operation, in-

dependent of those which now regulate the distribution of heat on the surface of the globe, to produce a higher temperature at that Tertiary period than could now, under any circumstances, here prevail; and, admitting the operation of ordinary climatal laws in producing a lower relative temperature at other Tertiary periods, it nevertheless follows, that, although such a relatively lesser heat can be accounted for by the refrigerating influences that have been alluded to, the generally higher temperature of the Tertiary period cannot be explained by any extent of variation dependent upon the ordinary climatal conditions possible in these latitudes. Consequently we infer, as far as the analogy can be trusted, that the mean temperature of this part of the globe was considerably warmer during the Lower Eocene period, and during the London Clay period in particular, than it now is.

After the period of the Bagshot Sands succeeded untold ages which have left no traces of their formations, or therefore of the life-existences, in this district. Possibly during part of it, the land here was dry land. It was at a much later time, long after our London Clay period, that the continent of Europe received its last and most important stamp,—one bringing it more to the state in which it now exists. The change was that caused by the elevation of the Alps, which, protruding through strata of later date than the London Clay, formed new watersheds and new rivers, and must have effected the configuration as well as climate of the whole of Europe.

The only other phænomena that we now have to notice, are those following the removal from this area of so large a portion of the London Clay and of the Bagshot Sands. This removal here gave rise to the great valley—termed of denudation—of the Thames, leaving, as I showed you in my last Lecture, a few high hills around, like pillars in some old pit, to tell us how high the land had once been, where all else of the ground around has been excavated and washed away (fig. 19, p. 35). At the same time, or soon afterwards, there was scattered over this and the London district generally the gravel of distant and complex origin we are now standing upon—ground probably trodden long before us by herds of the Elephant, Rhinoceros, Ox, Deer, Horse, and various other animals. And lastly, these have in their turn

passed away, leaving this land as it now is, little changed in its configuration from what it then was, but renewed with another population of plants and animals,—varied, mutually dependent, and beautiful as the preceding ones, but differing from all preceding ones by its association with and subordination to our own kind.

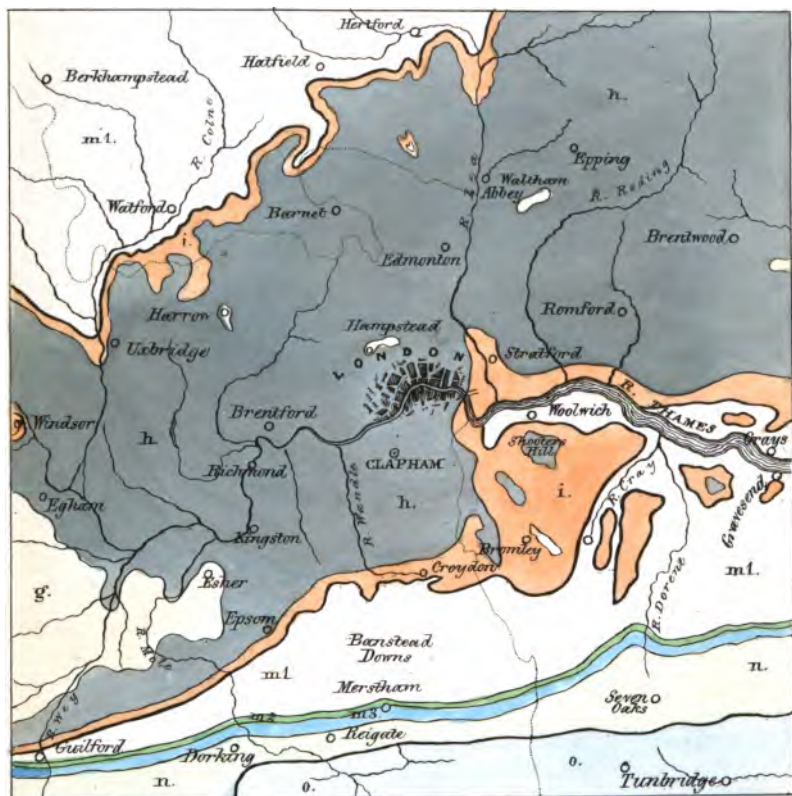
I trust that this short sketch, which is necessarily limited to the leading features and the more general details, may serve to give you some idea of the structure of the ground beneath us,—of its geological phases and changes,—and enable you to form some conception of the order, completeness, and harmony ruling in the organic life of the successive periods we have passed in review, consequently of the reality of that life, and of the vast duration of its coexisting time. And I can only express a hope that the interest of the subject, its variety and its grandeur, may lead some amongst you to join in further inquiries, the object of which is to interpret truthfully and earnestly those records of past creations, the memorials of which exist within our reach, although buried and obscured in the ground beneath our feet.



OUTLINE GEOLOGICAL MAP OF THE NEIGHBOURHOOD OF LONDON

by

J. PRESTWICH, F. G. S.

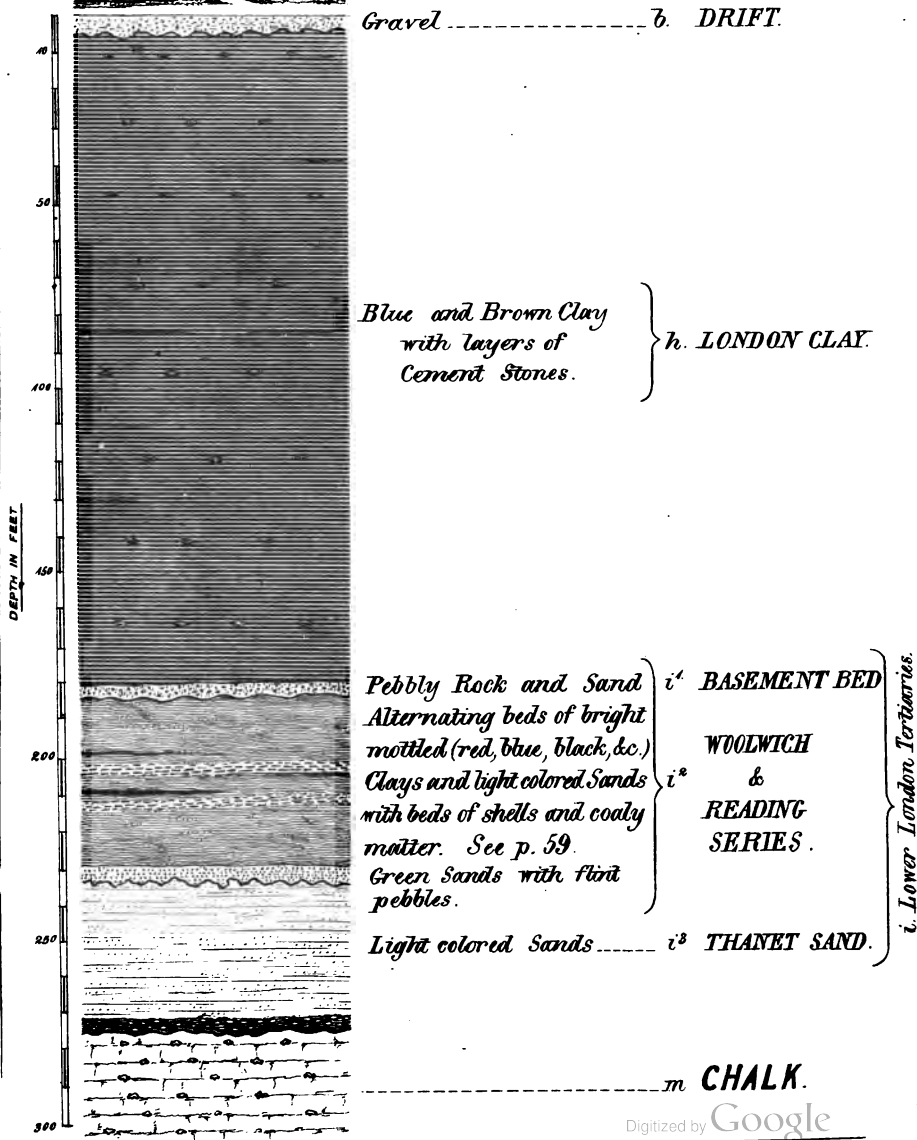


SECTION FROM LONDON TO REIGATE.



- | | |
|-----------------------------------|---------------------------|
| g Bagshot Sands. | mf Upper Greensand |
| h London Clay. | ms Gault. |
| i Lower London Tertiaries. | n Lower Greensand |
| ml Chalk. | o Wealden |

SECTION OF THE DRIFT AND LONDON TERTIARY STRATA AT CLAPHAM.



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